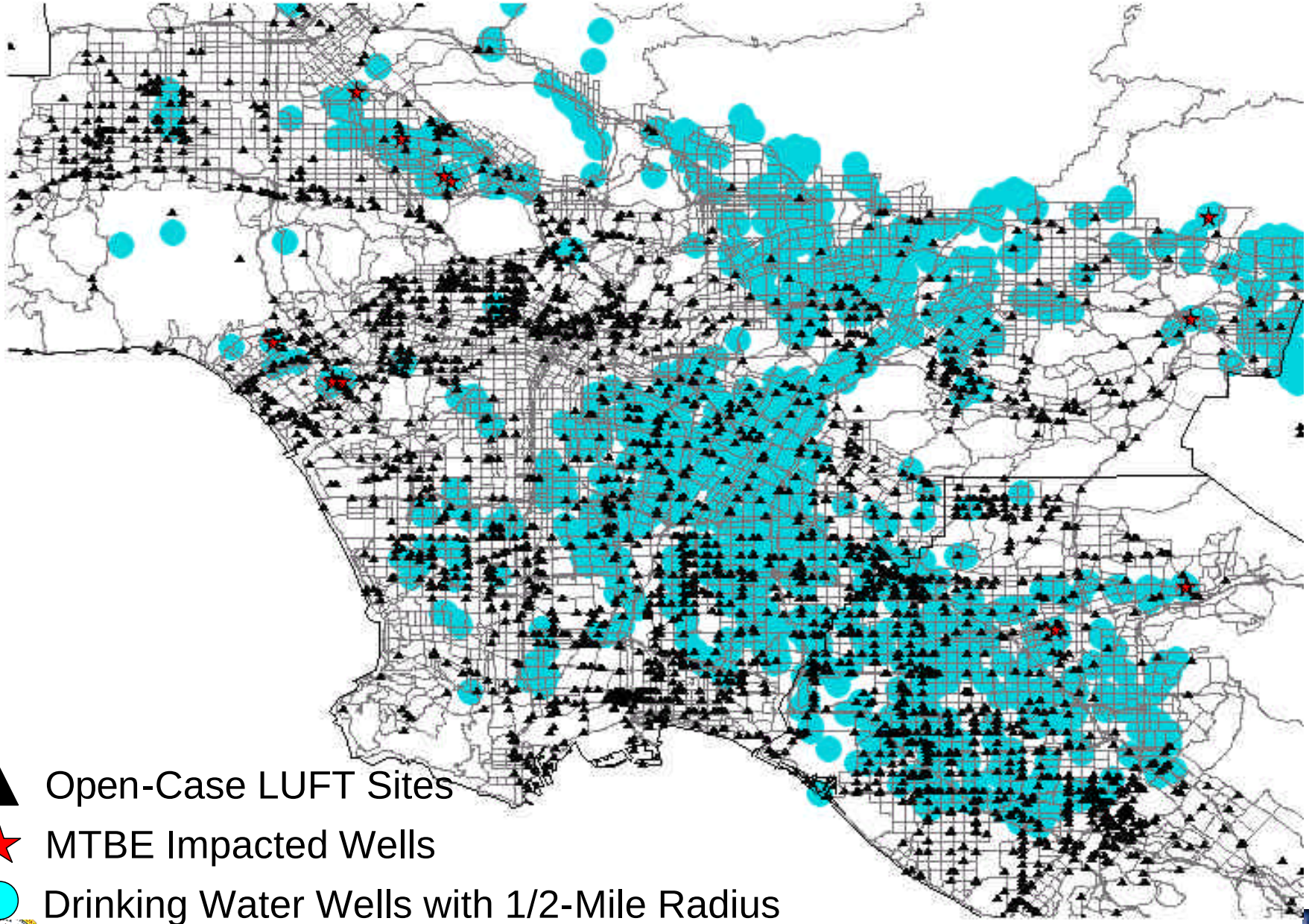
Water Resource Vulnerability Issues Associated with the Increased Use of Ethanol and Alkylates in Fuels

Dr. Brendan P. Dooher
Lawrence Livermore National Laboratory
April 11, 2001

Los Angeles Basin



▲ Open-Case LUFT Sites

★ MTBE Impacted Wells

● Drinking Water Wells with 1/2-Mile Radius

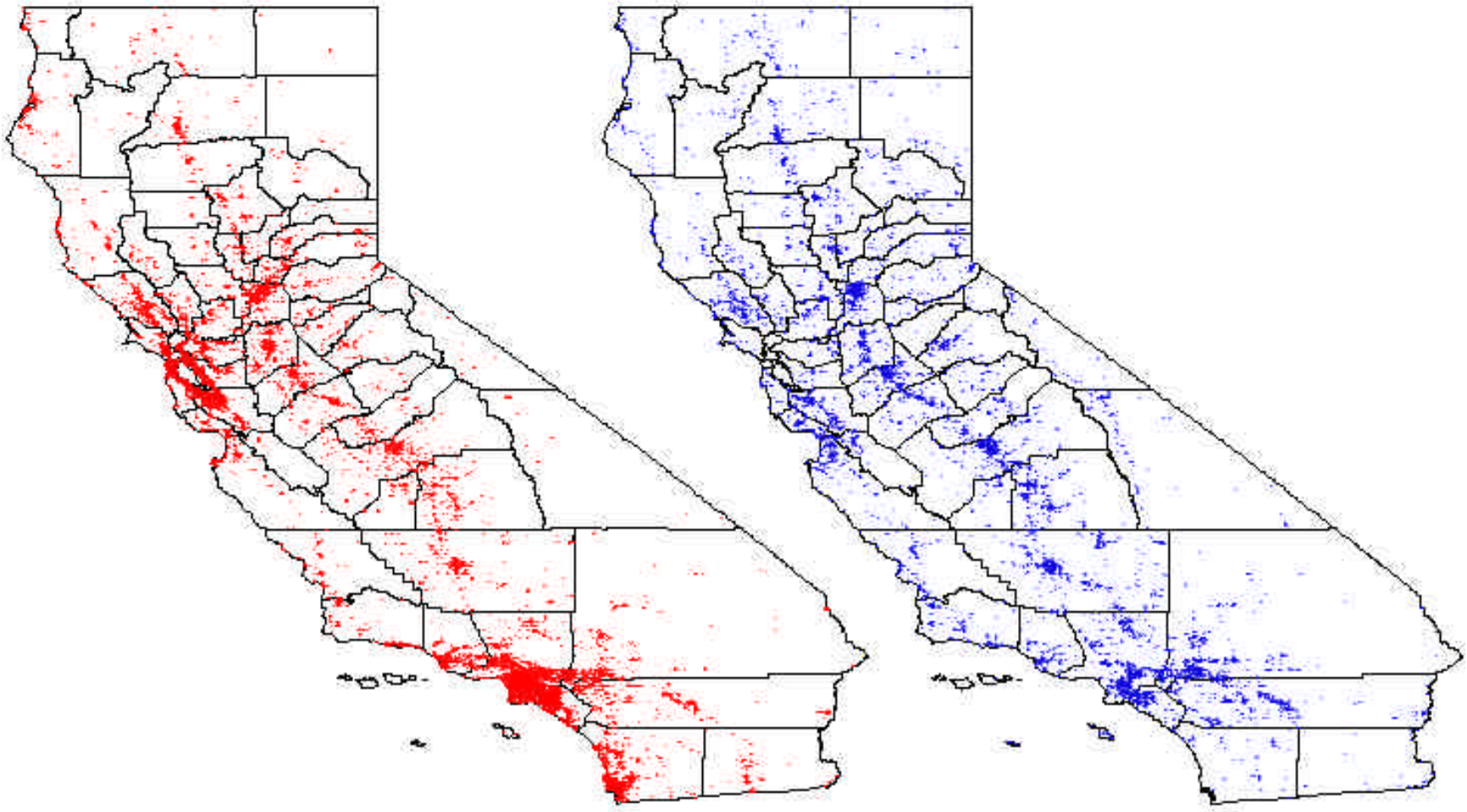
Constable, 1999: The World Atlas of Archeology

"Oldest archeological evidence of ethanol production (wine-making) in findings dated 5500 BC located 11 ft deep in sediments at the Mesopotamian City of Ur along the Euphrates river near the modern day City of Kuait.."

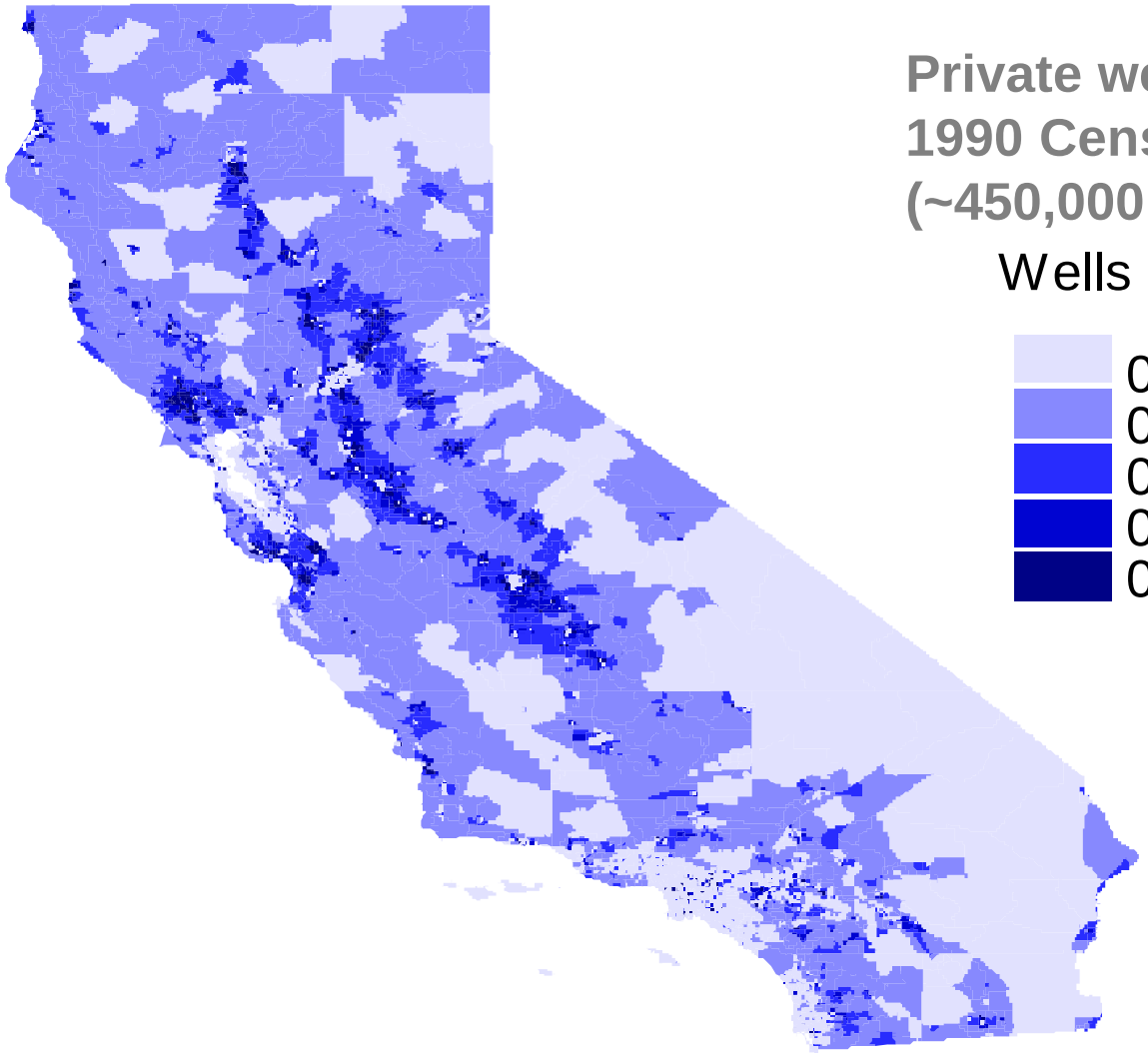
Locations of leaking underground fuel tanks (LUFTs) and public wells in California

LUFT Sites

Public Groundwater Sources



Density of private wells in California

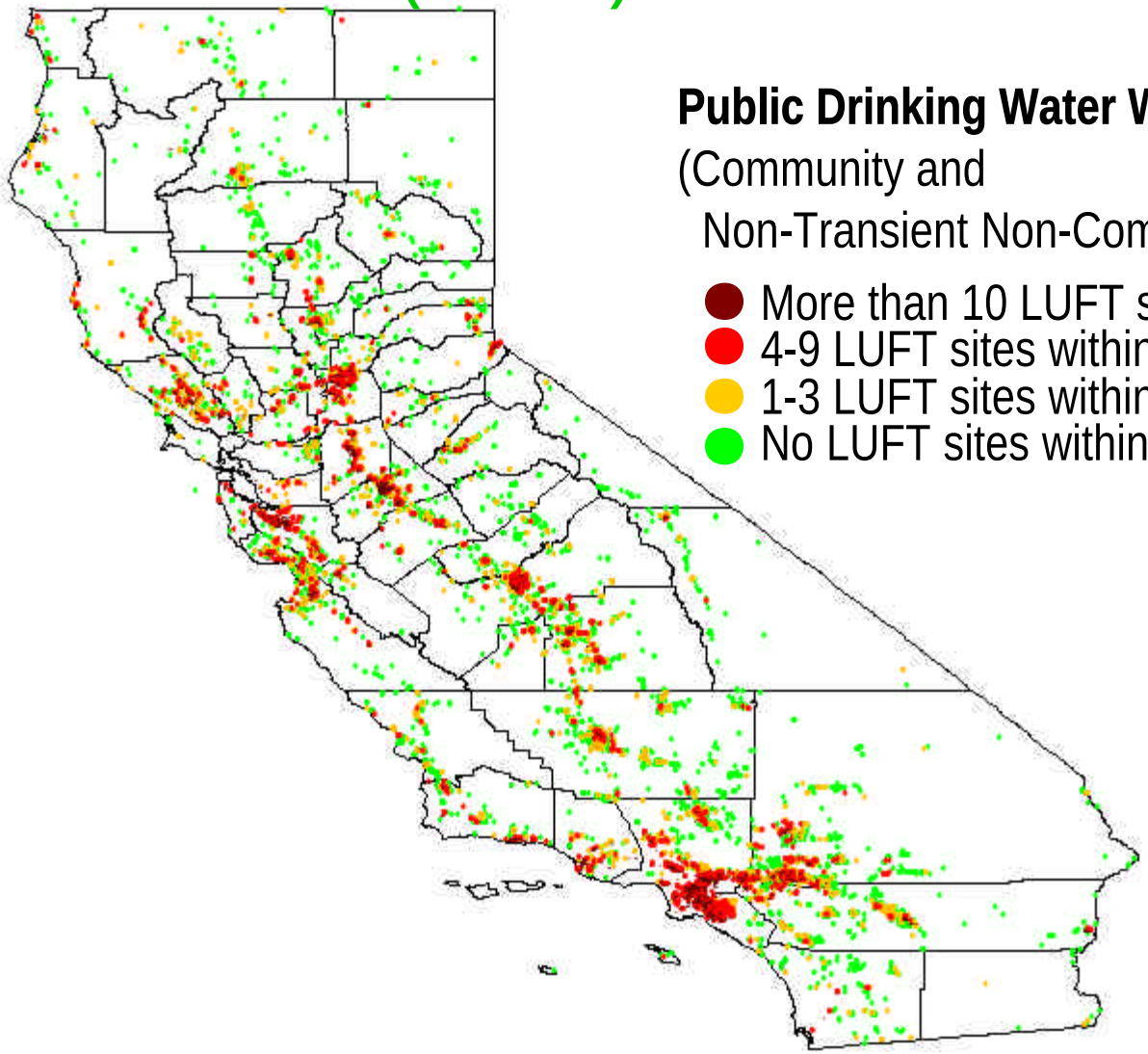


Private well density based on 1990 Census Block Group Data (~450,000 Private Wells)

Wells per Acre

- 0
- 0.00 - 0.01
- 0.01 - 0.03
- 0.03 - 0.08
- 0.08 - 4.50

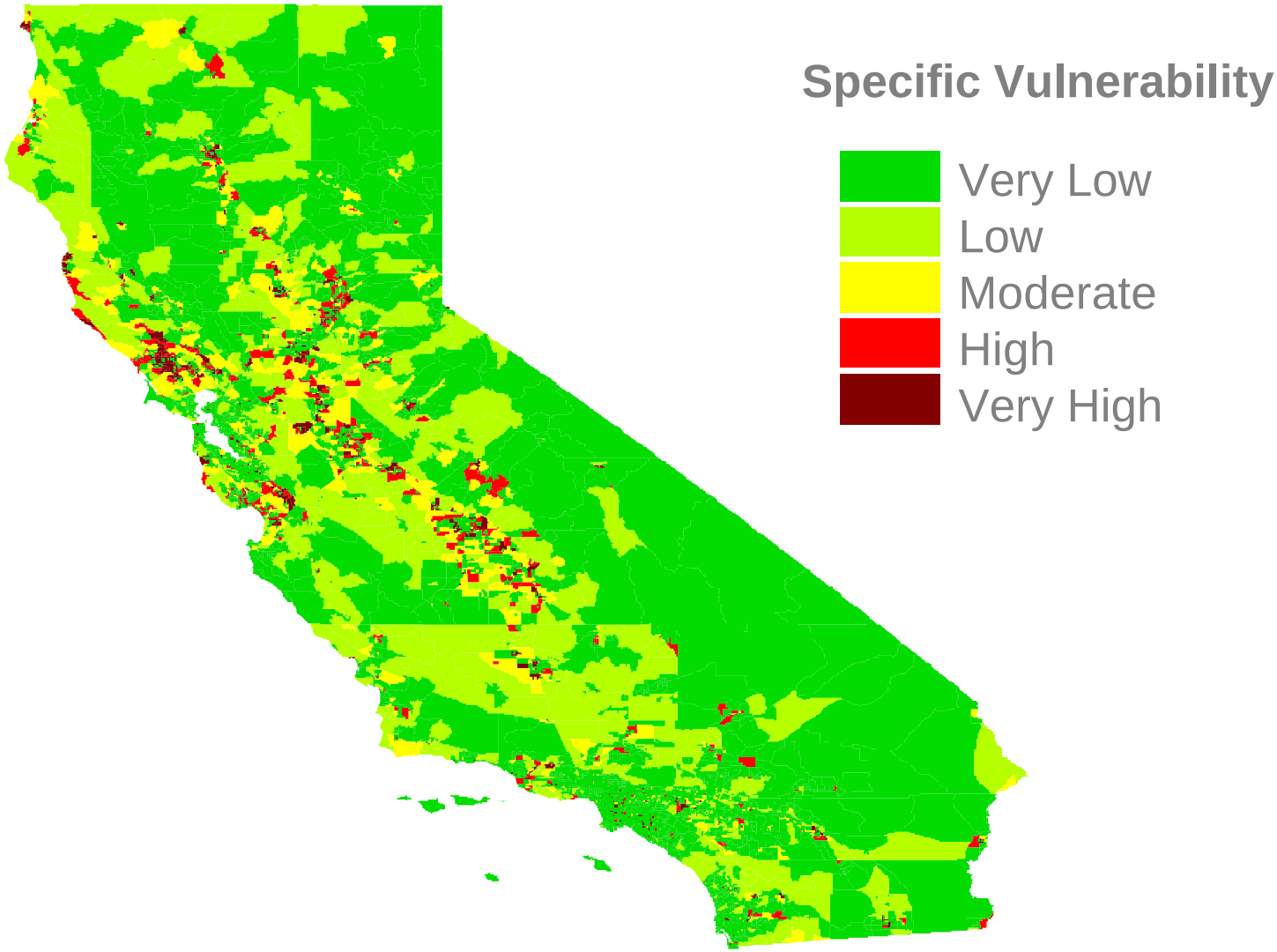
Public Drinking Water Wells in California: Estimated Number of Leaking Underground Fuel Tank (LUFT) Sites Within 1/2 Mile

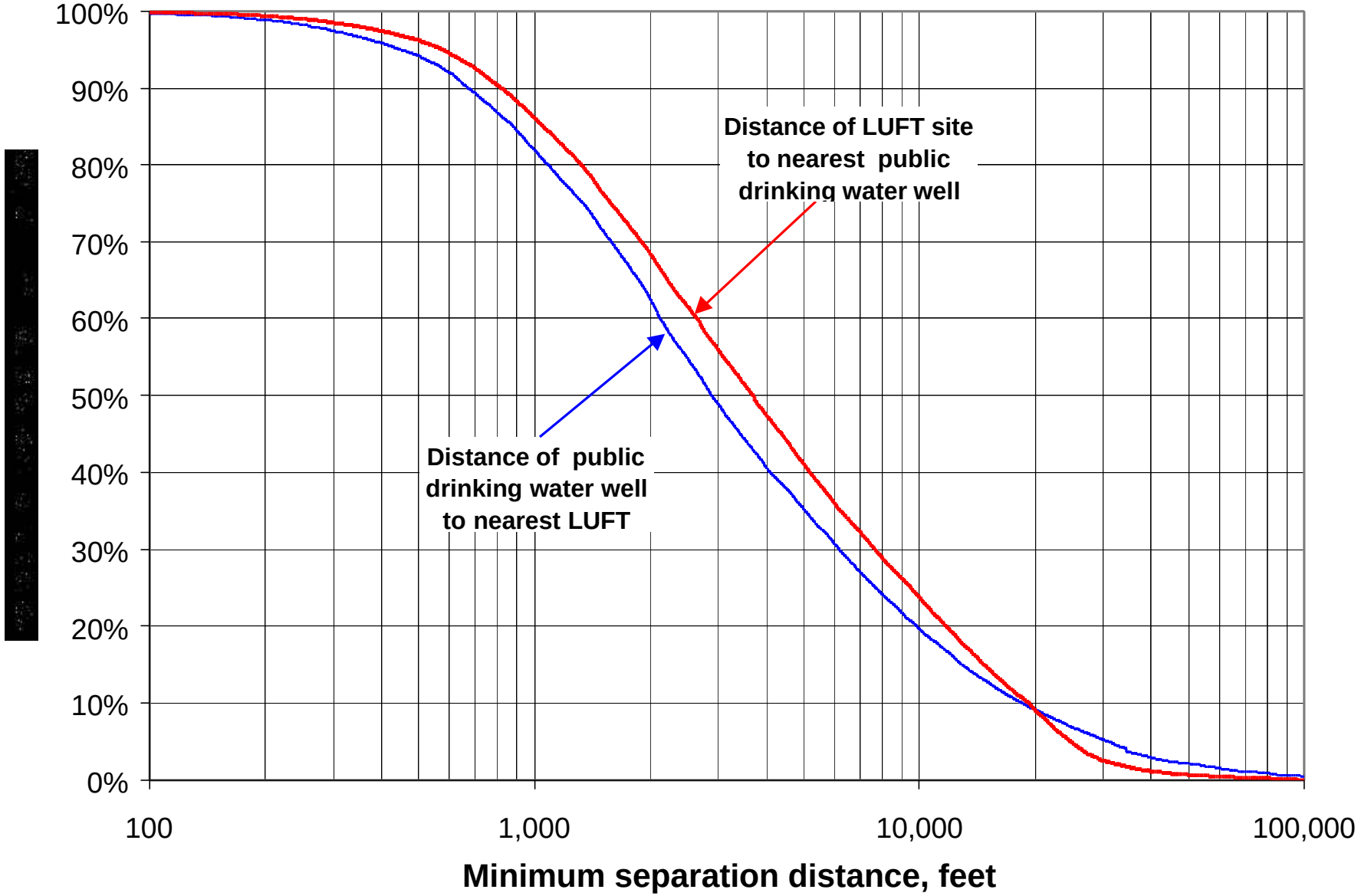


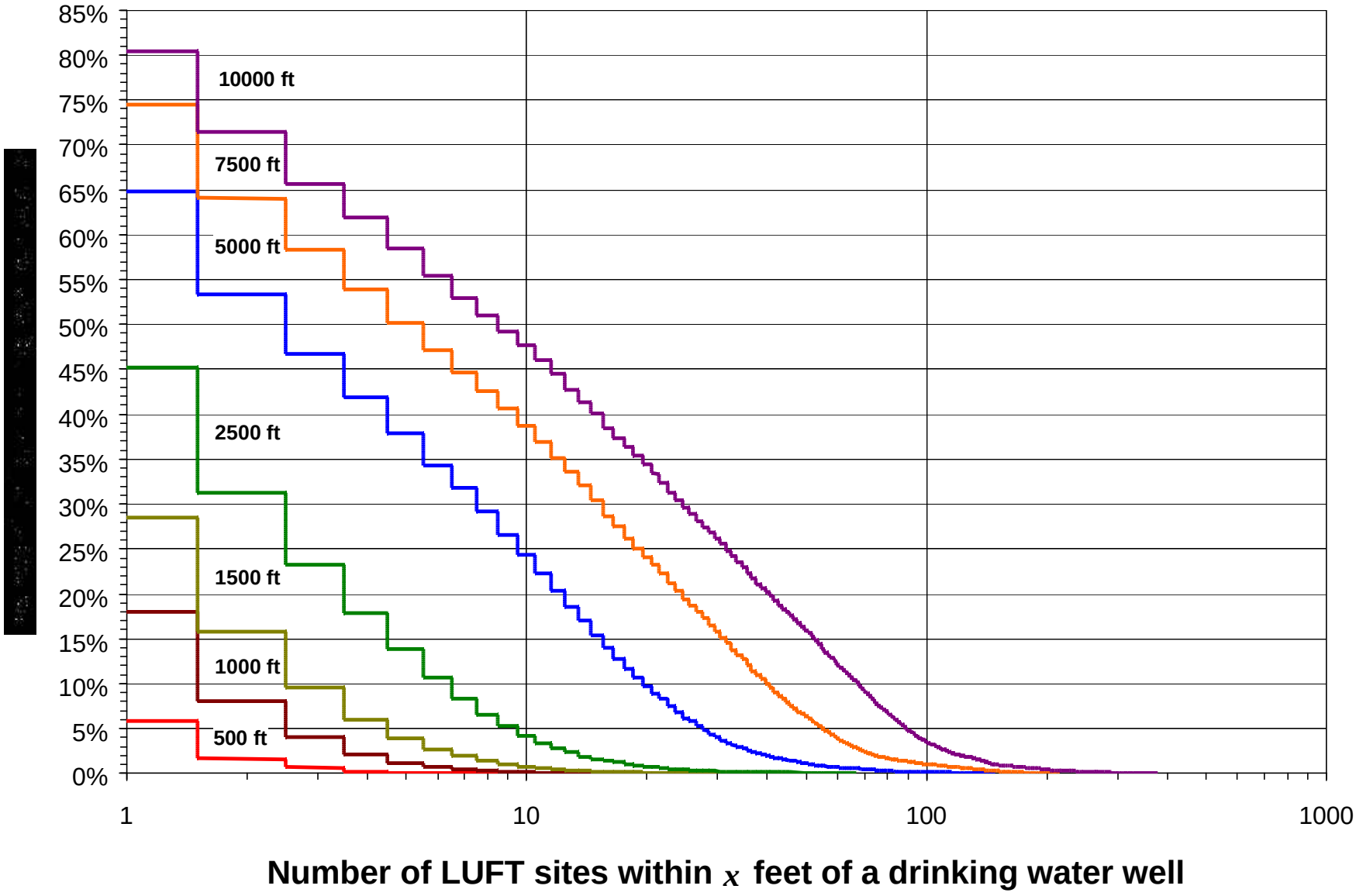
Public Drinking Water Wells
(Community and
Non-Transient Non-Community)

- More than 10 LUFT sites within 1/2 mile
- 4-9 LUFT sites within 1/2 mile
- 1-3 LUFT sites within 1/2 mile
- No LUFT sites within 1/2 mile

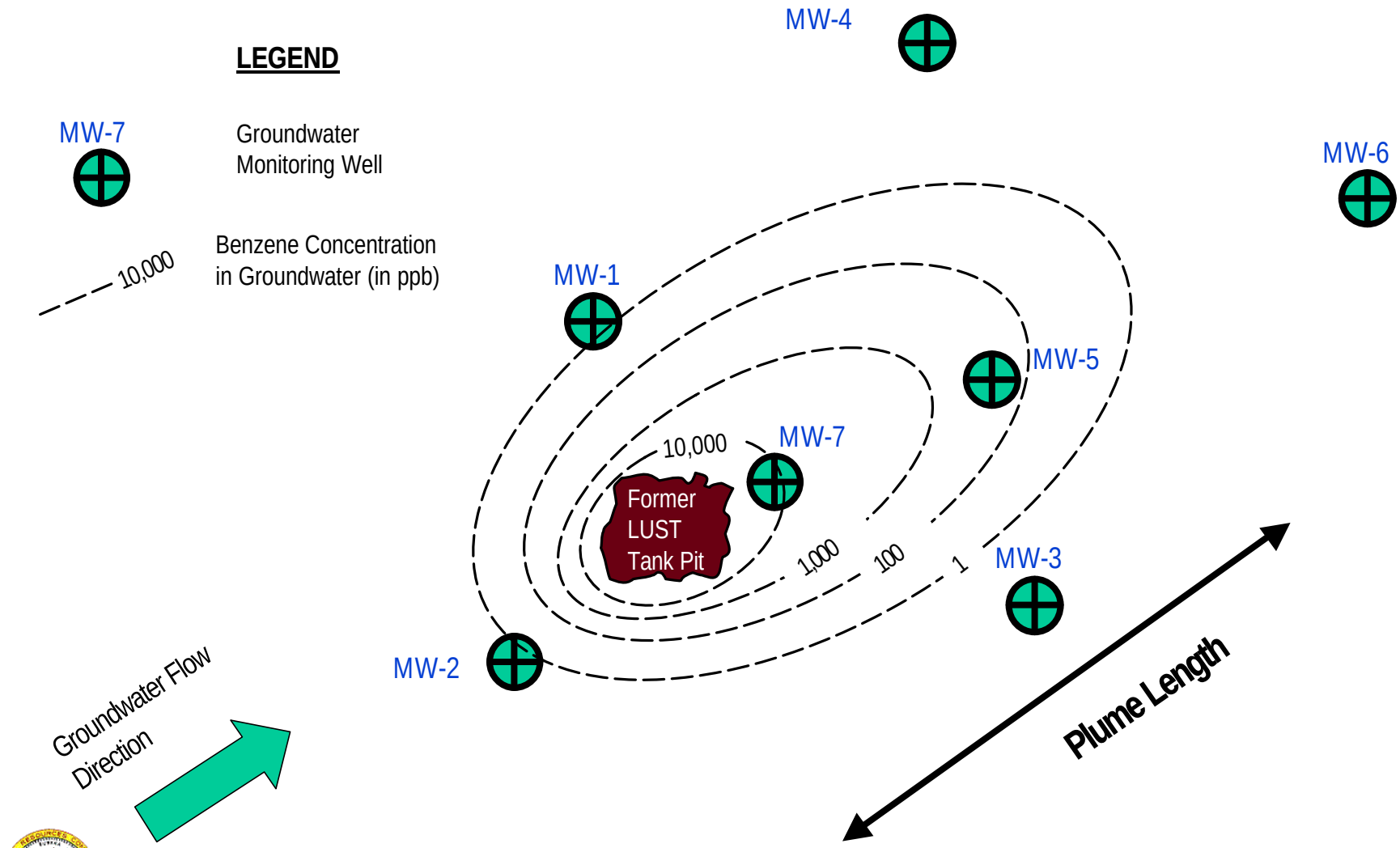
Co-locations of private water wells with leaking underground tanks



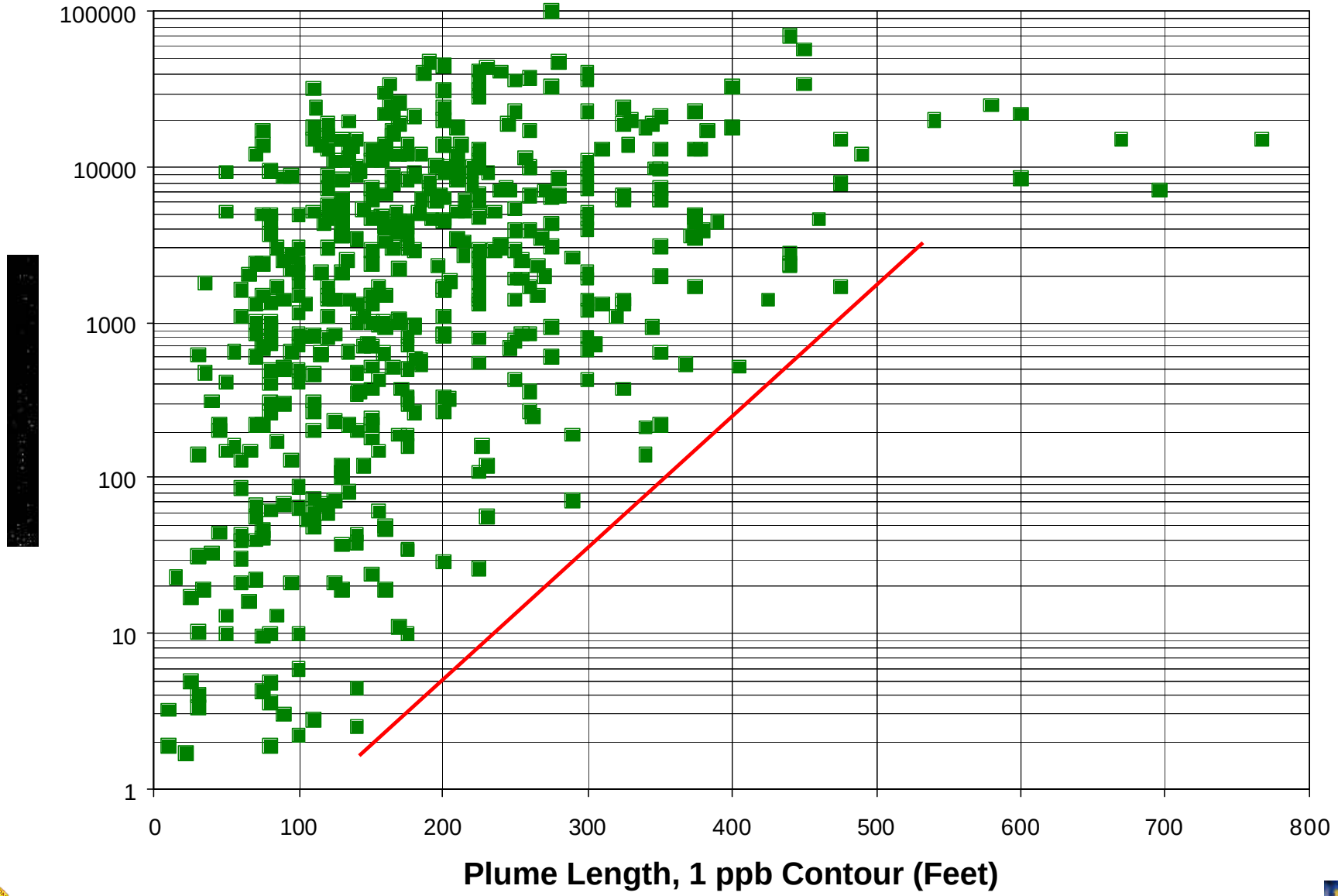

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
100
1,000
10,000
100,000
Distance of LUFT site to nearest public drinking water well
Distance of public drinking water well to nearest LUFT
Minimum separation distance, feet


85%
80%
75%
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
10000 ft
7500 ft
5000 ft
2500 ft
1500 ft
1000 ft
500 ft
1
10
100
1000
Number of LUFT sites within x feet of a drinking water well

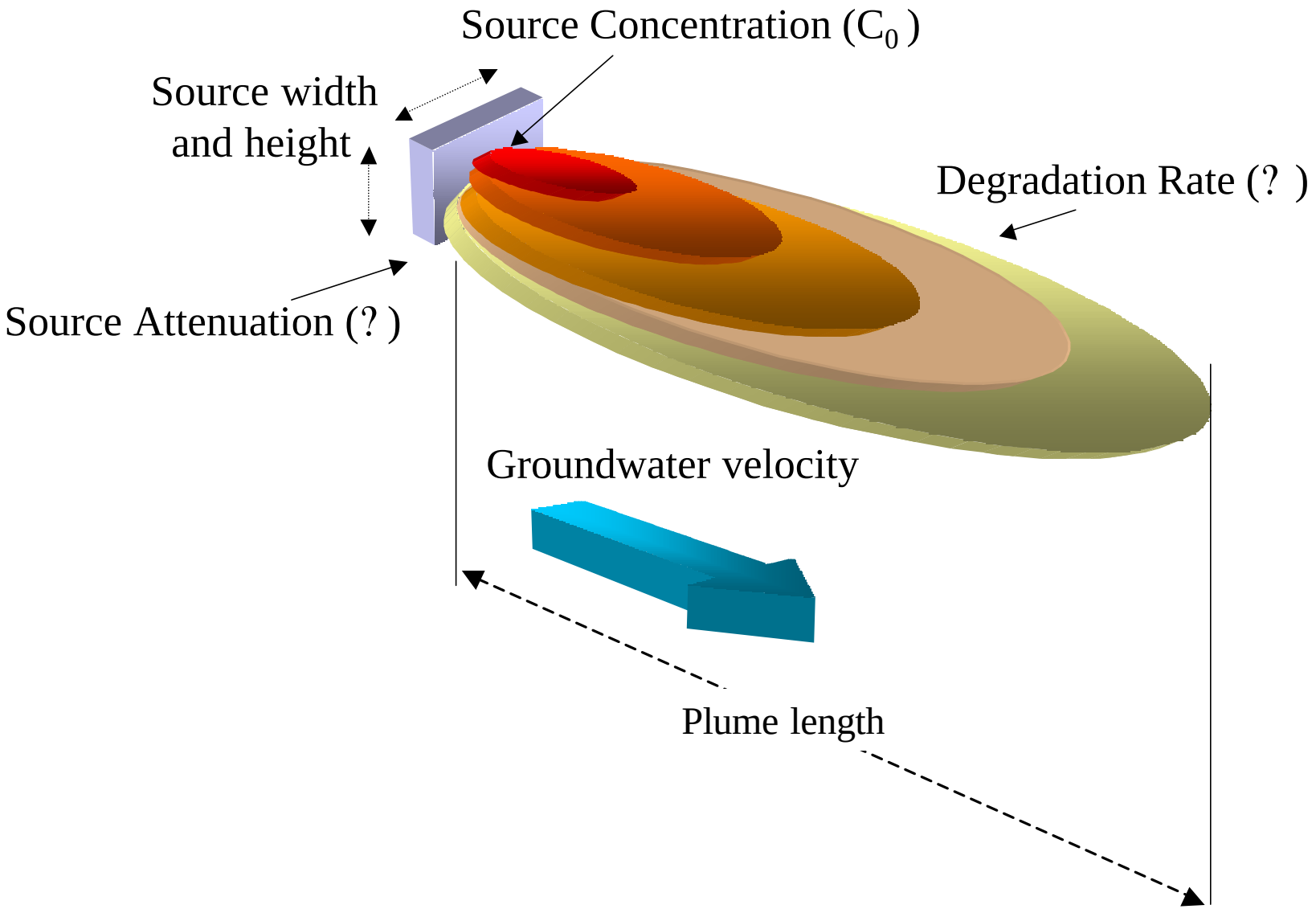
Determination of measured benzene plume lengths



Benzene plume lengths



Monte Carlo analysis with *Cleary and Ungs* (1978) model



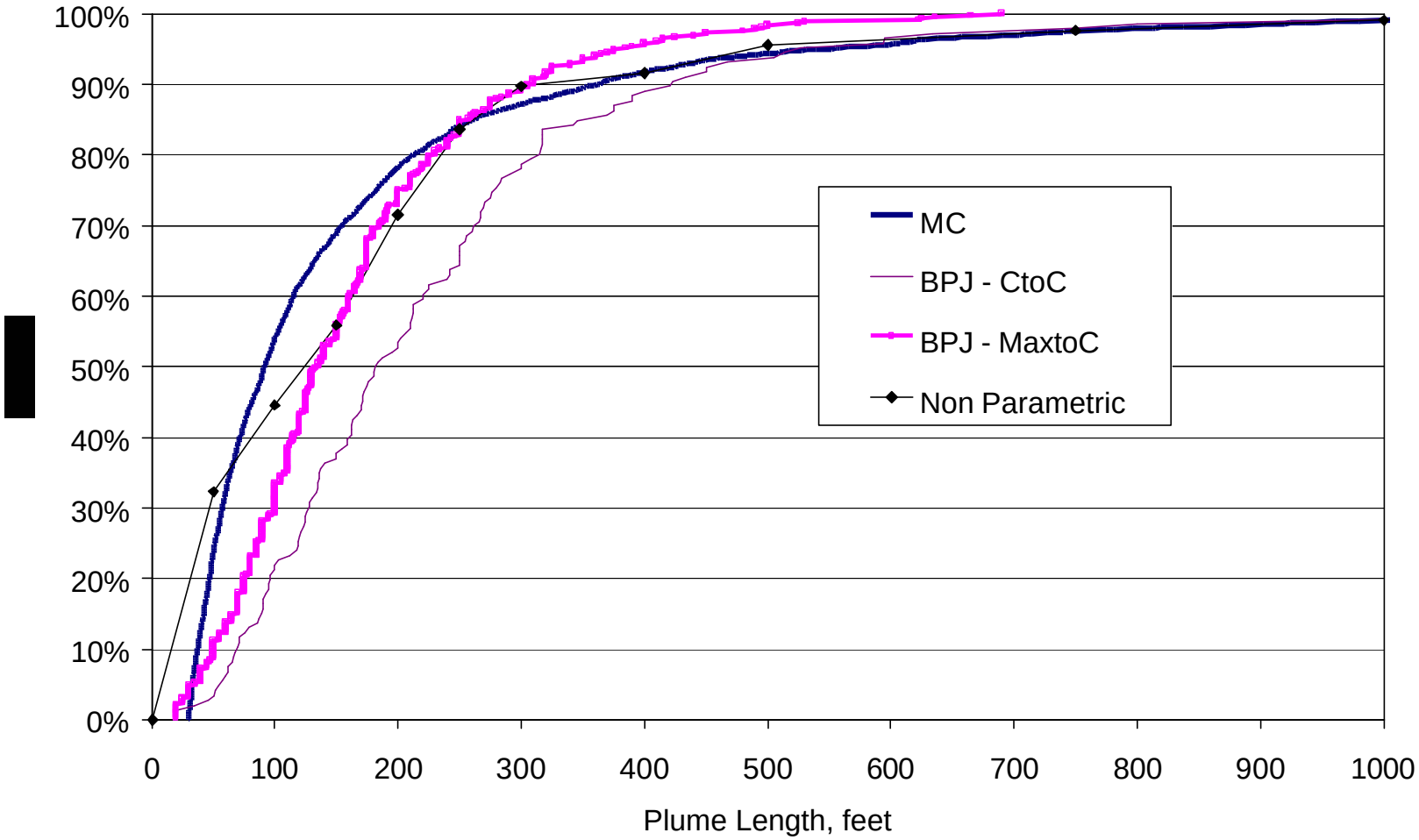
Monte Carlo analysis with *Cleary and Ungs* (1978) model
Model Inputs*:

- Source Concentration - 1999 Data from 4,300 LUFT sites
- Source Attenuation Half-life - Based on maximum benzene measurements from 1,000 LUFT sites from 1988 to 1994
- Source Width - Based on tank dimensions
- Source Height - Based on variations in groundwater depth
- Hydraulic Conductivity - Measured from 100 LUFT sites
- Hydraulic Gradient - Measured from 1,000 LUFT sites
- Dispersivity (based on Gelhar et al., 1992)
- Plume length taken at 5 ppb contour
- No degradation rate

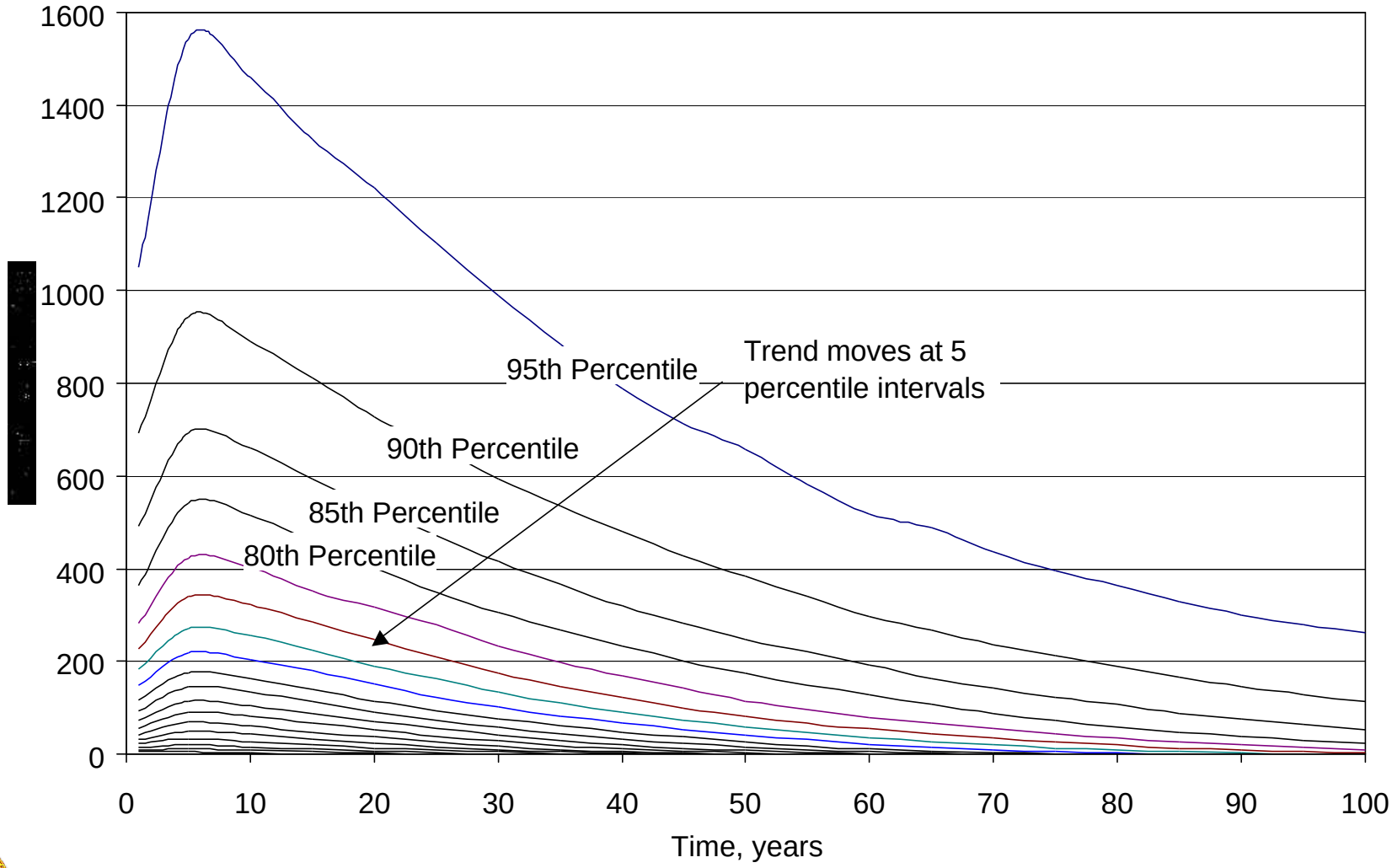
Data used as model inputs are derived from approximately 1,000 LUFT sites from throughout California

*Based on results measured at California LUFT sites, Dooher, March 1998

Simulated vs. measured plume lengths



Plume growth and decay for benzene

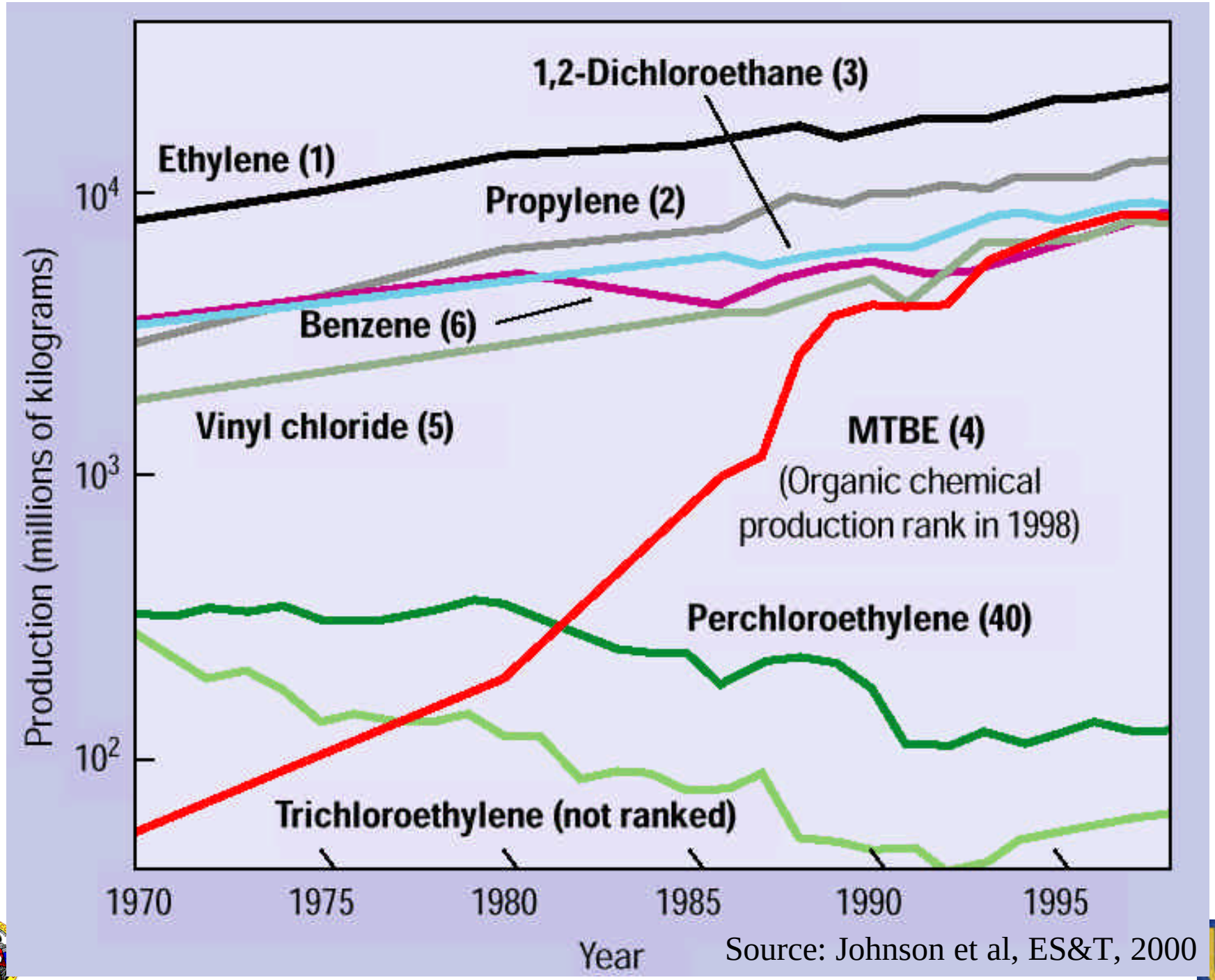


It Was a Dark and Stormy Night in Santa Monica

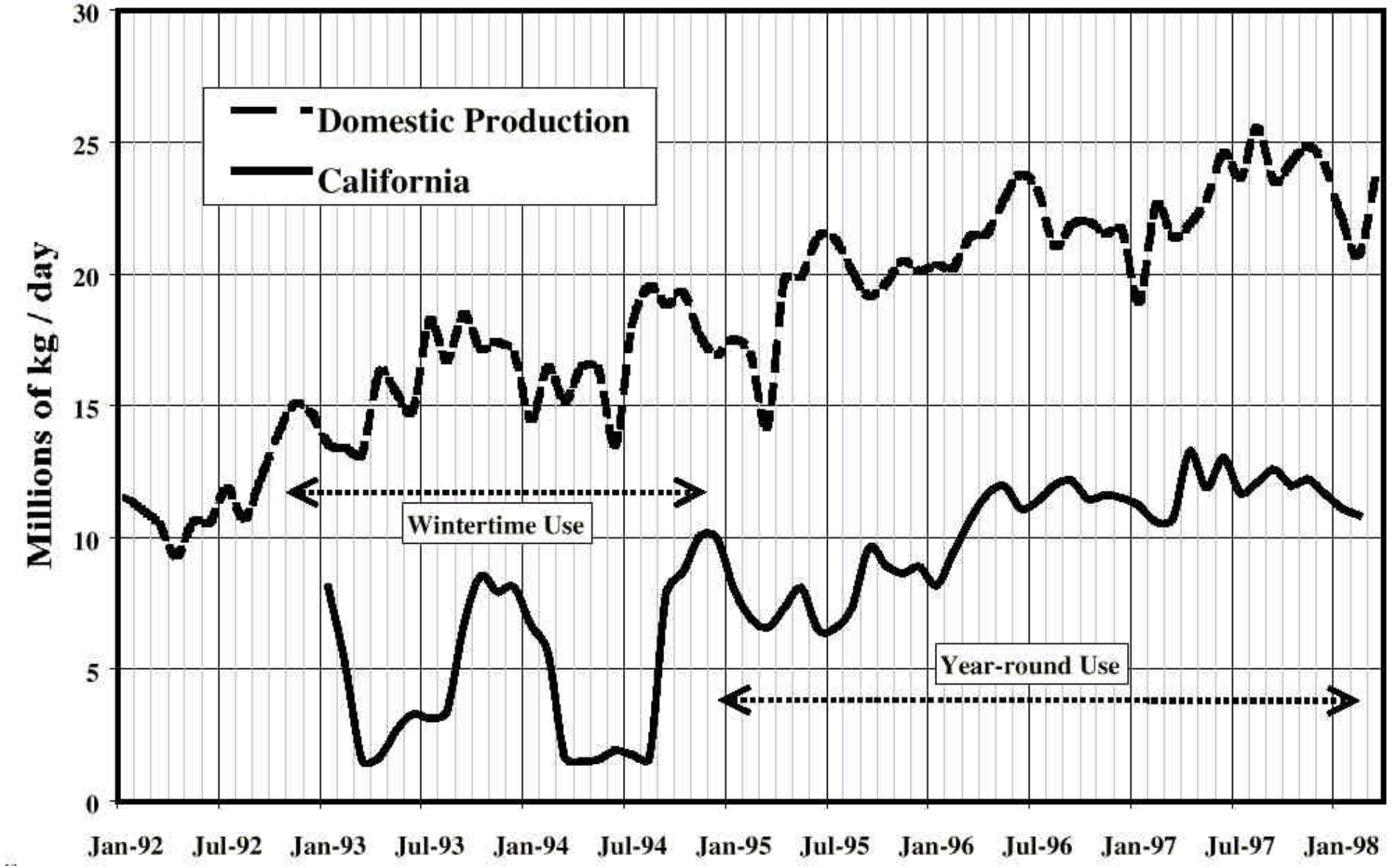
and MTBE was lurking...

Comparison of maximum MTBE Concentrations detected at LUFT sites throughout California

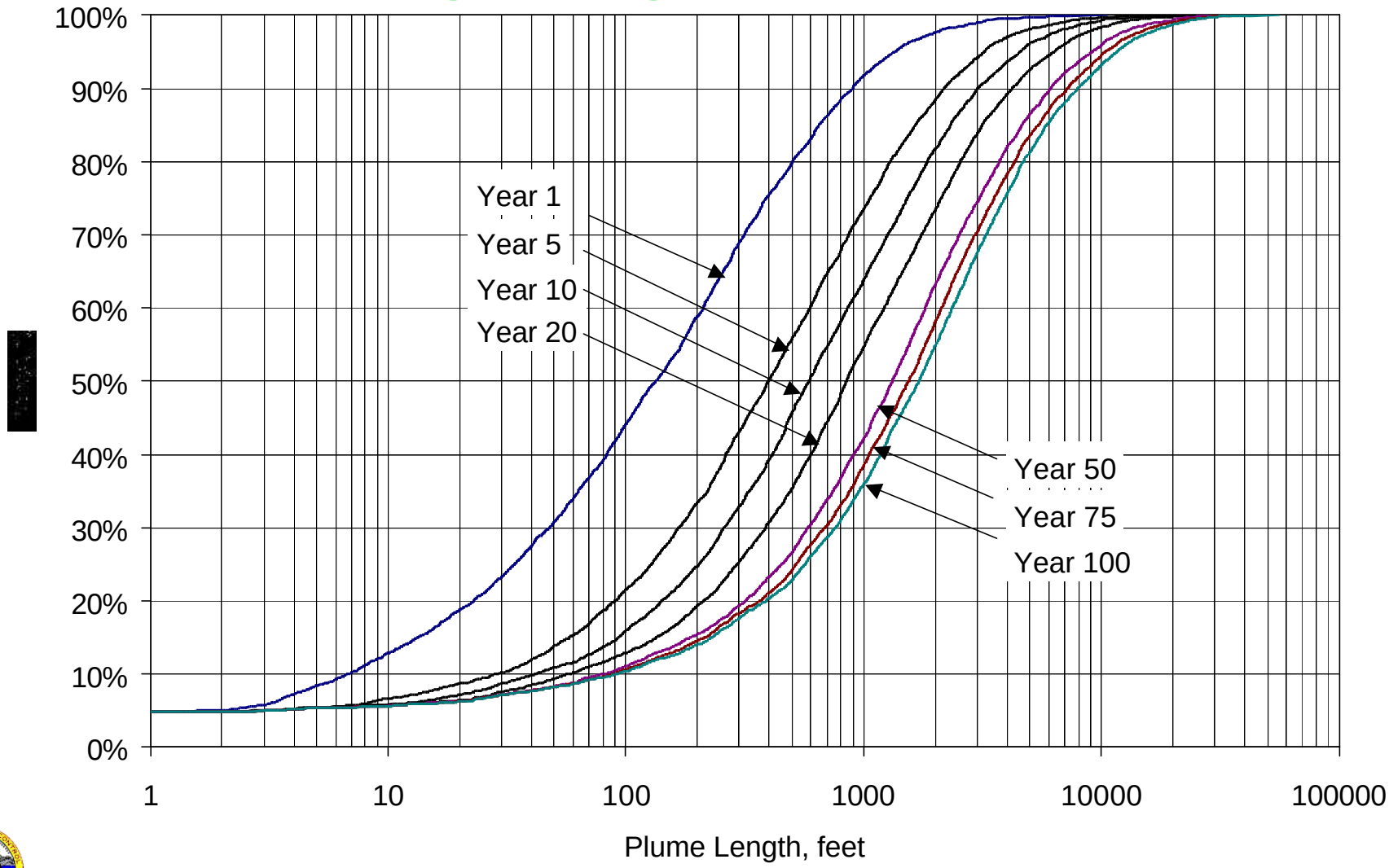
ppb (parts per billion)	'95 - '96	January '99
	236 Sites	4300 Sites
<5	25%	23%
5-50	11%	12%
50-200	11%	11%
200-1000	18%	17%
1000-5000	16%	14%
5000-20000	13%	13%
20000-100000	4%	7%
>100000	1%	3%



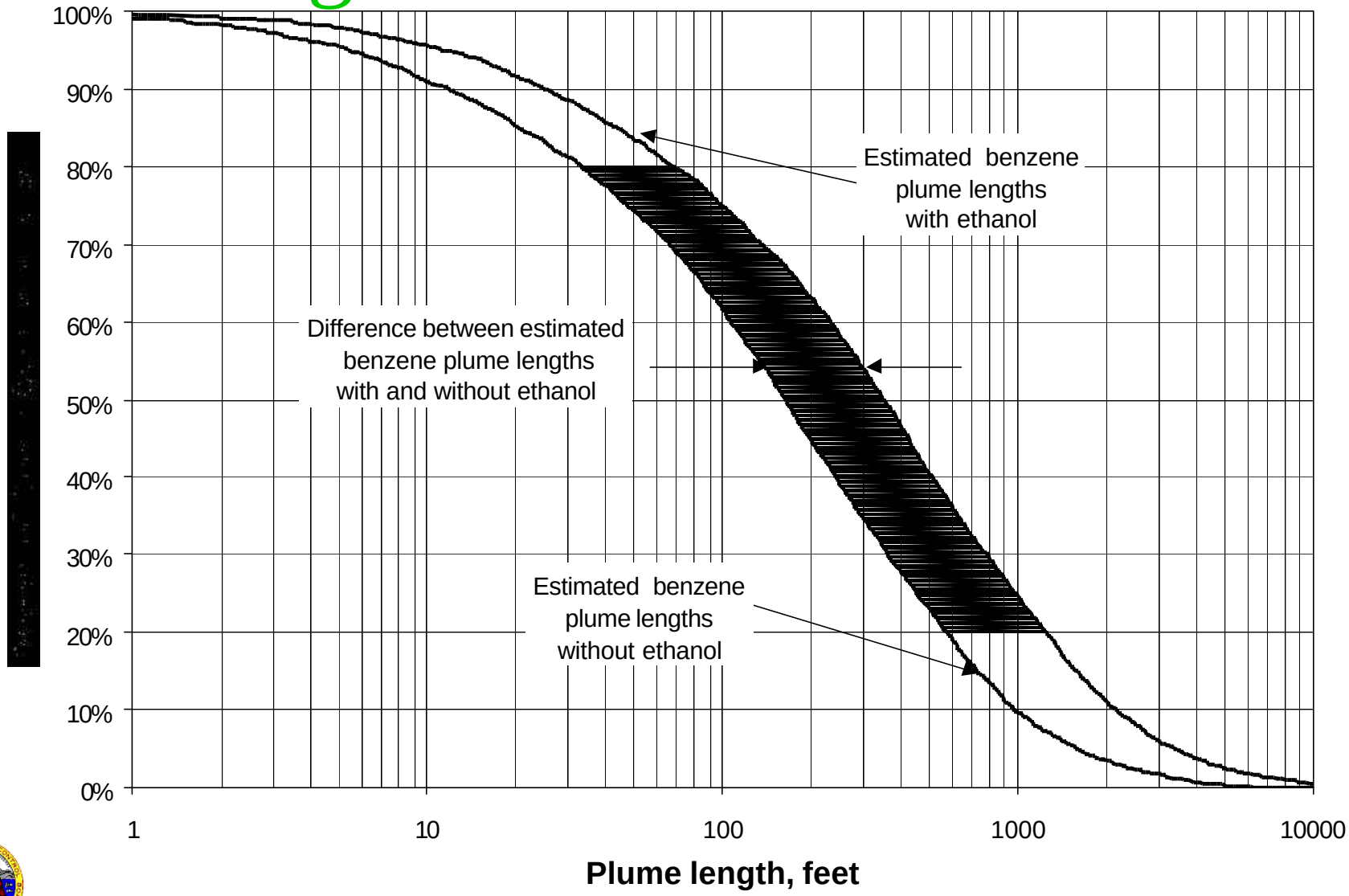
Source: Johnson et al, ES&T, 2000


Domestic Production
California
Millions of kg / day
30
25
20
15
10
5
0
Wintertime Use
Year-round Use
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98

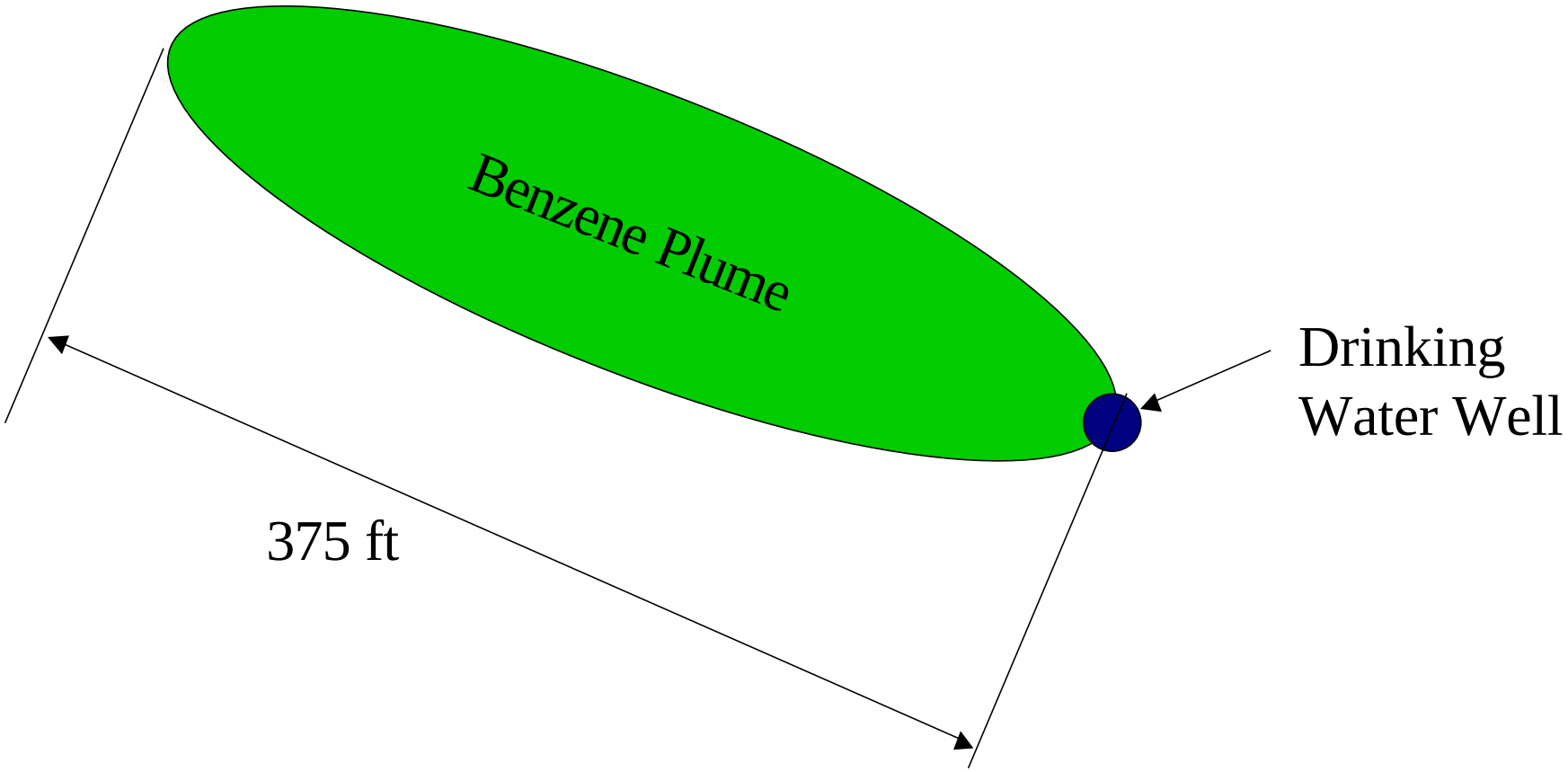
MTBE plume length over time
(non-degrading, constant source)



Difference in benzene plume lengths with ethanol added



Relation between well and LUFT site



Probabilities

Assumptions:

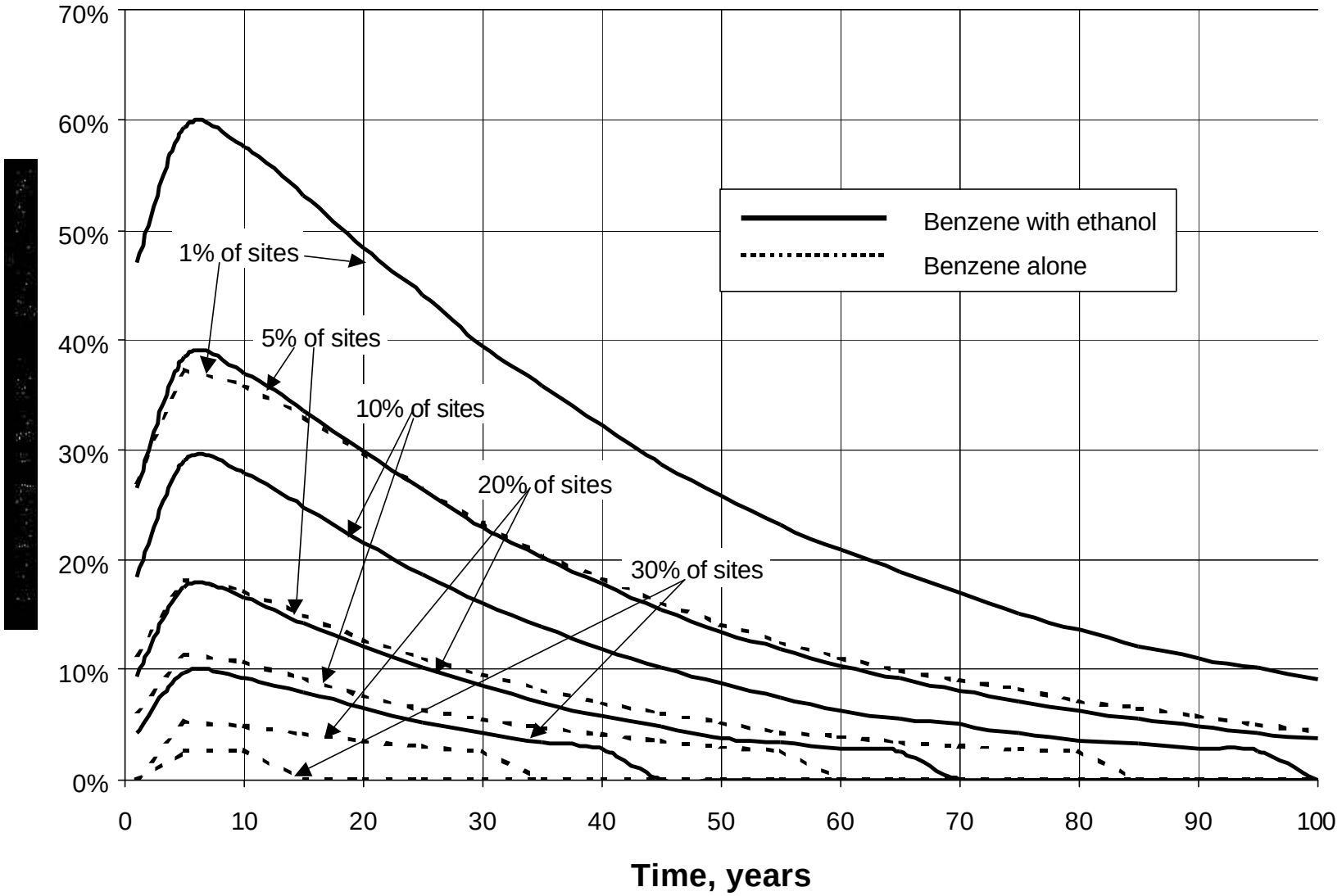
- Hydrogeologic features - unchanged.
- Well distributions - unchanged.
- LUFT site distributions - unchanged.

- The only factor that changes (significantly) is plume length.
  - Change in plume length becomes the metric for assessing the increased probability of threat...

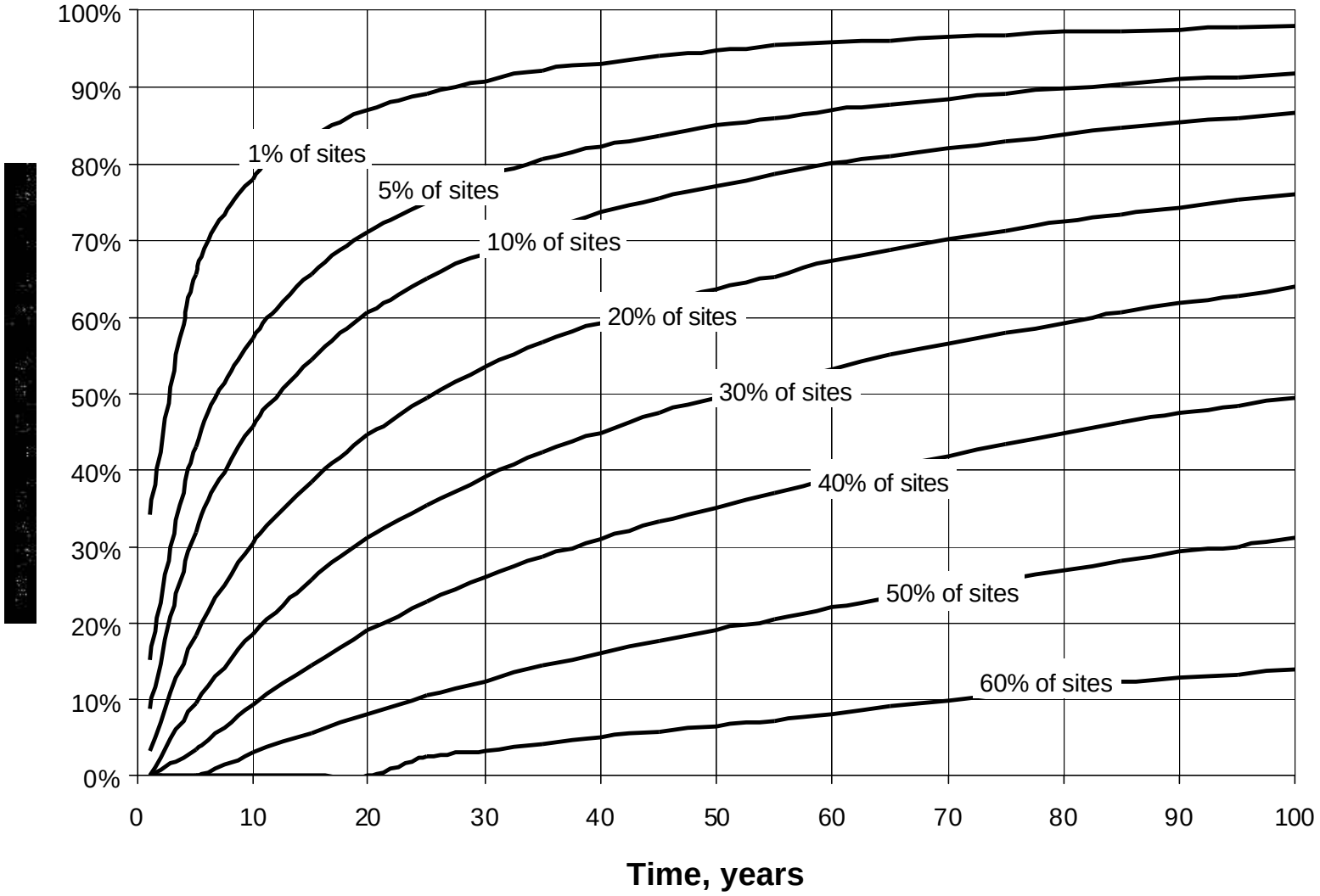
Probabilities

- Probability that plume travels 375 ft - 9%
  - Without ethanol
- Probability that plume travels 375 ft - 15%
  - With ethanol
- Change in probability - 67% increased chance of plume impacting well

Increased probability of threat: benzene alone and with ethanol

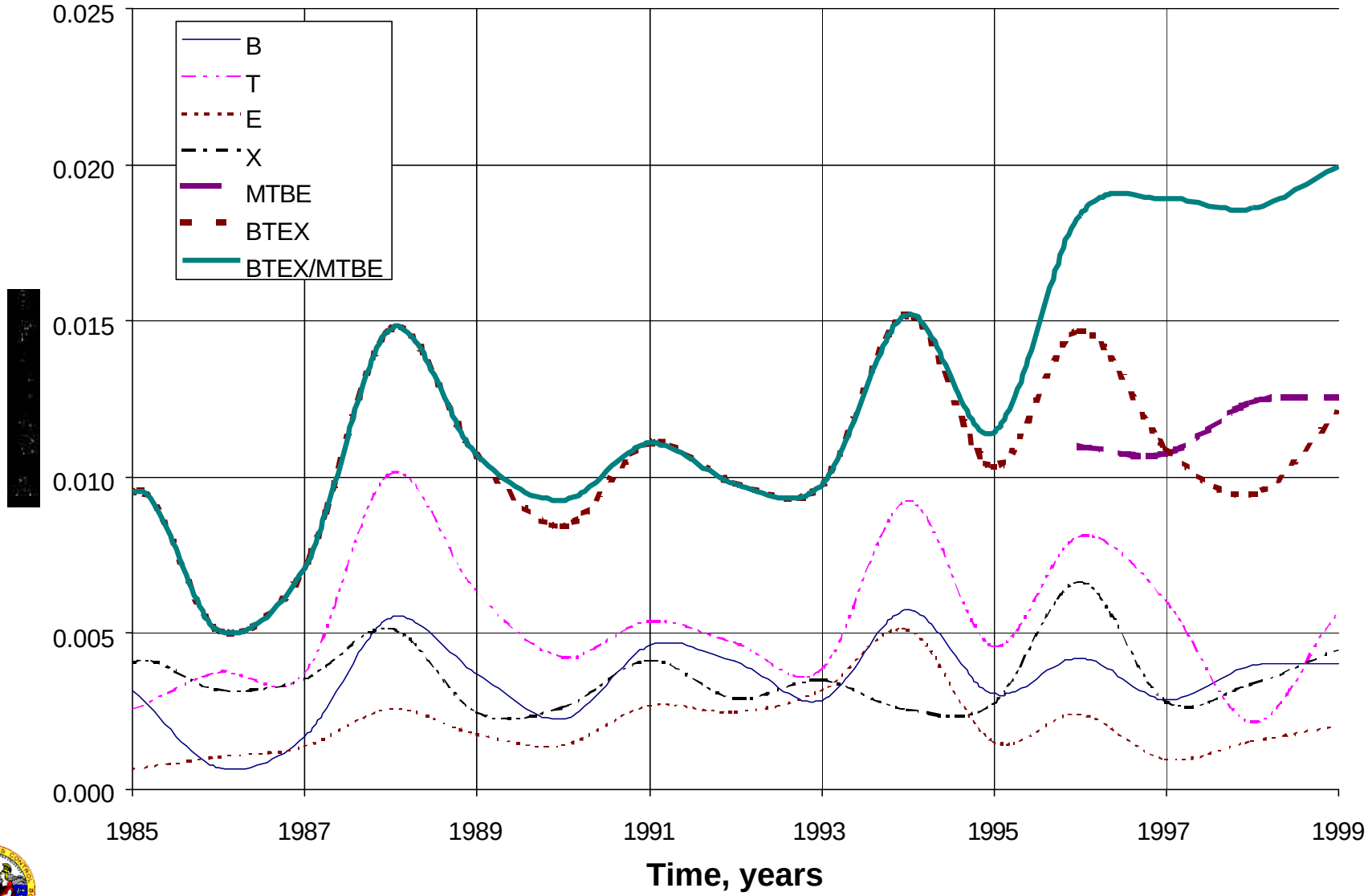


Increased probability of threat: MTBE

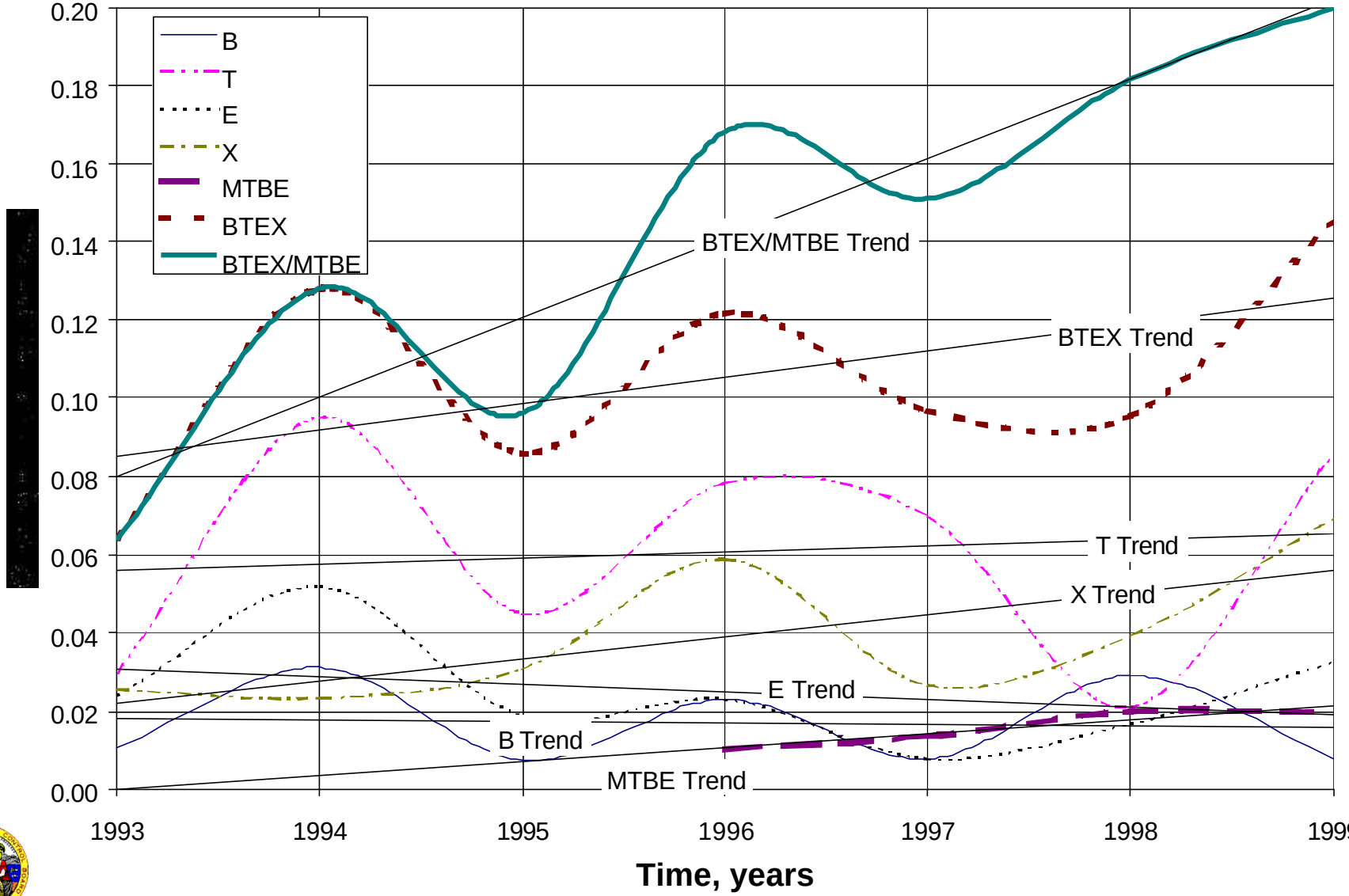


Drinking water wells

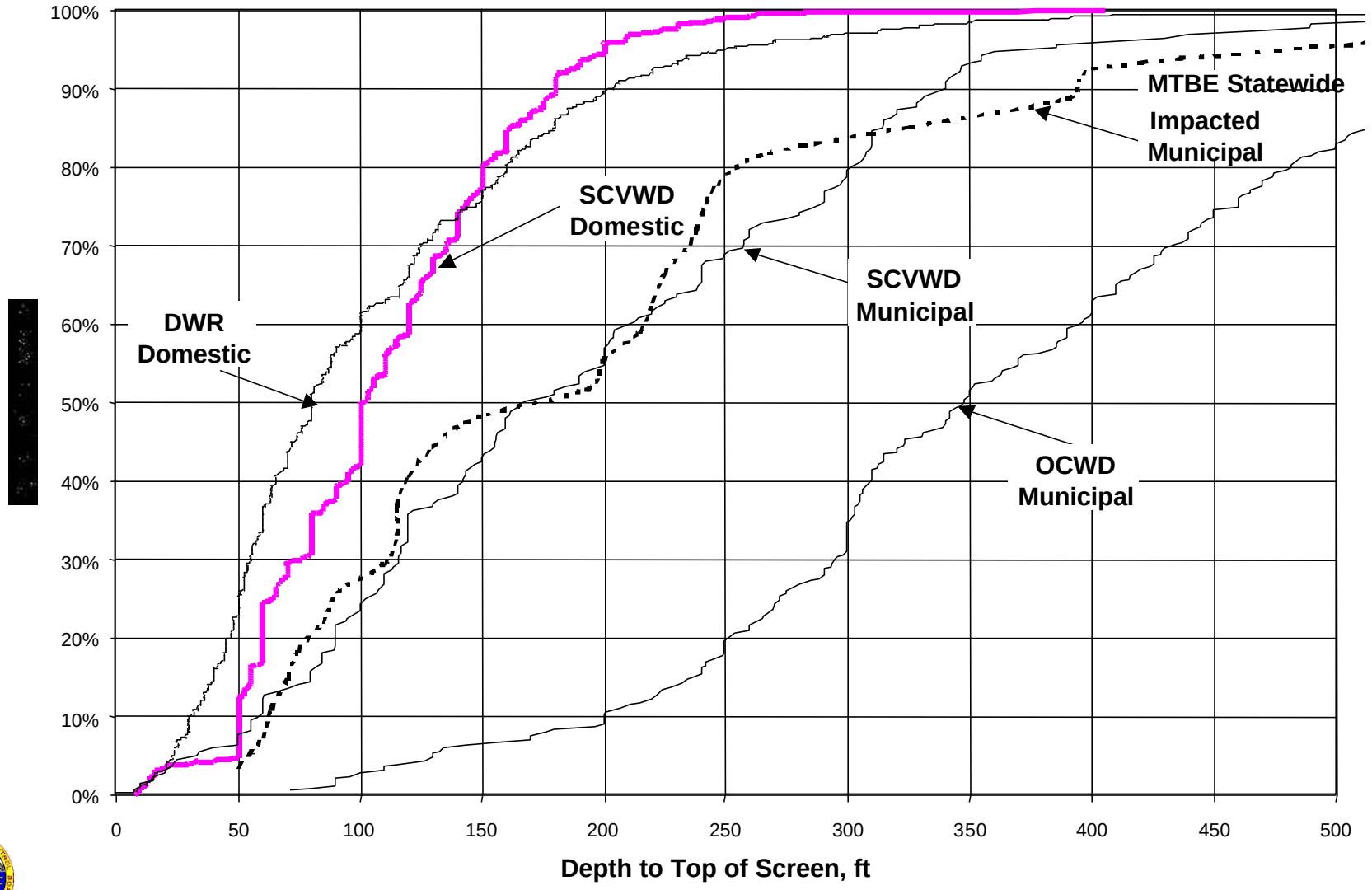
Detection rate of BTEX and MTBE in drinking water sources throughout California

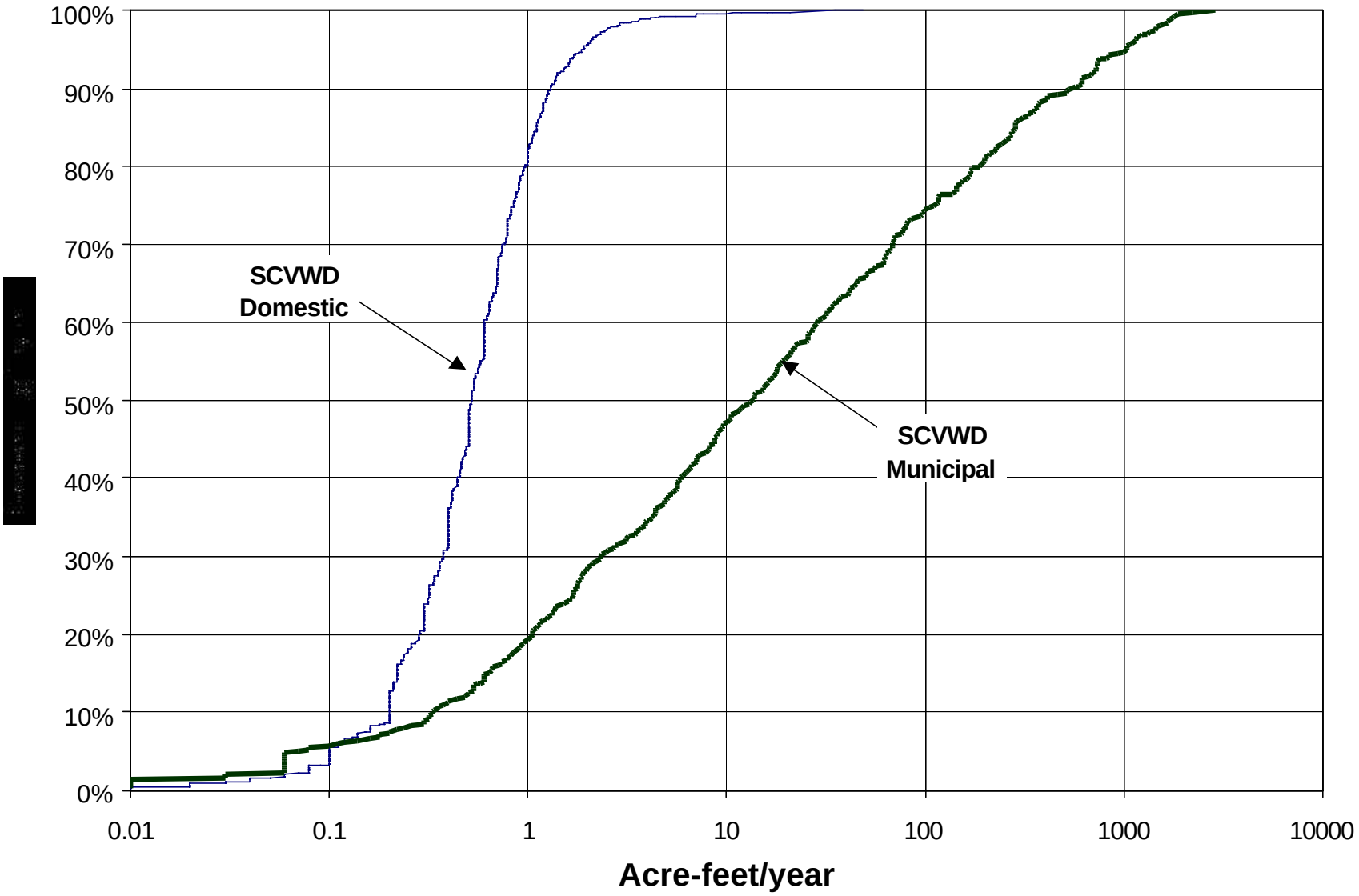


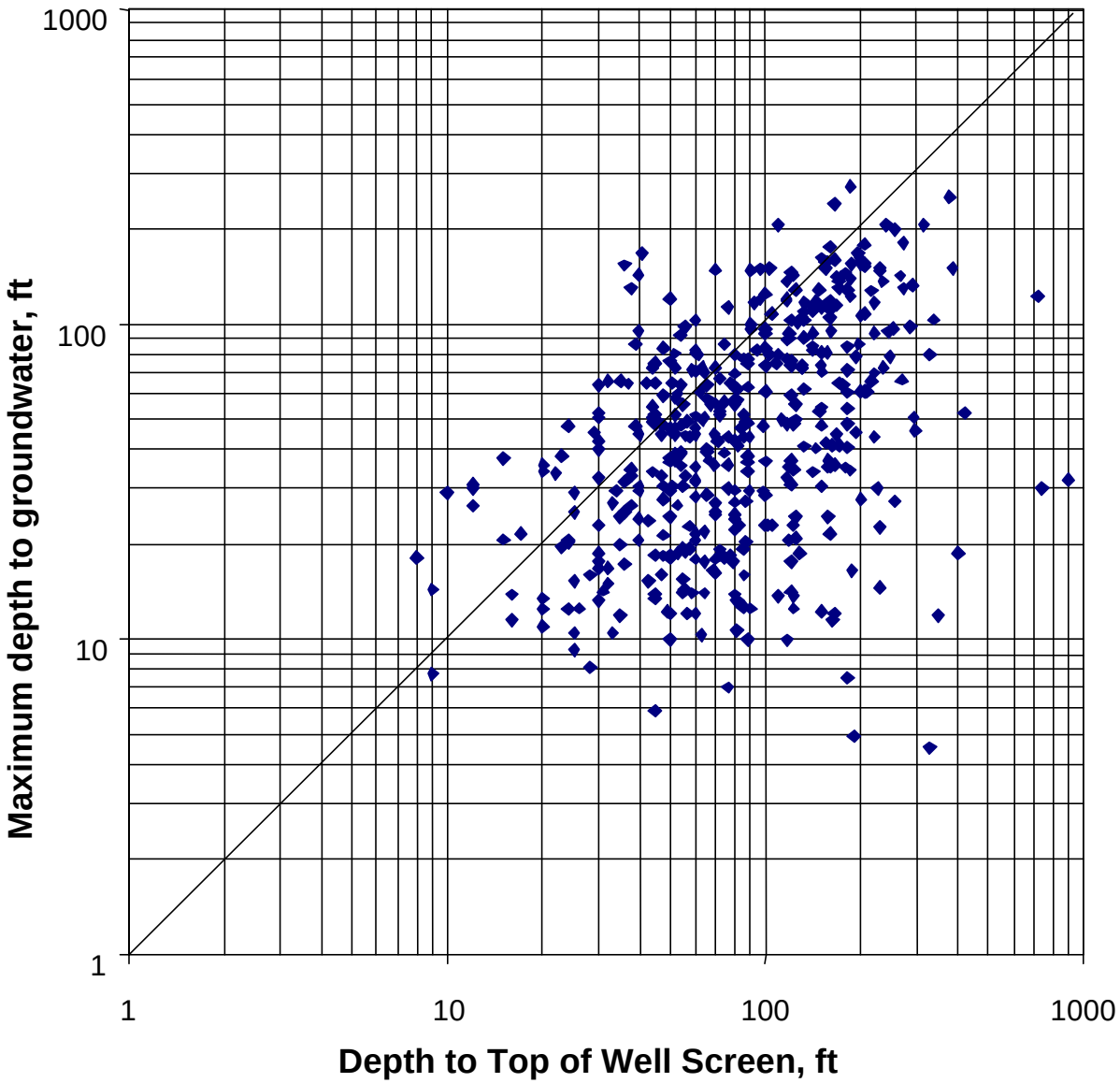
Change in detection rate of BTEX and MTBE in drinking water sources throughout California

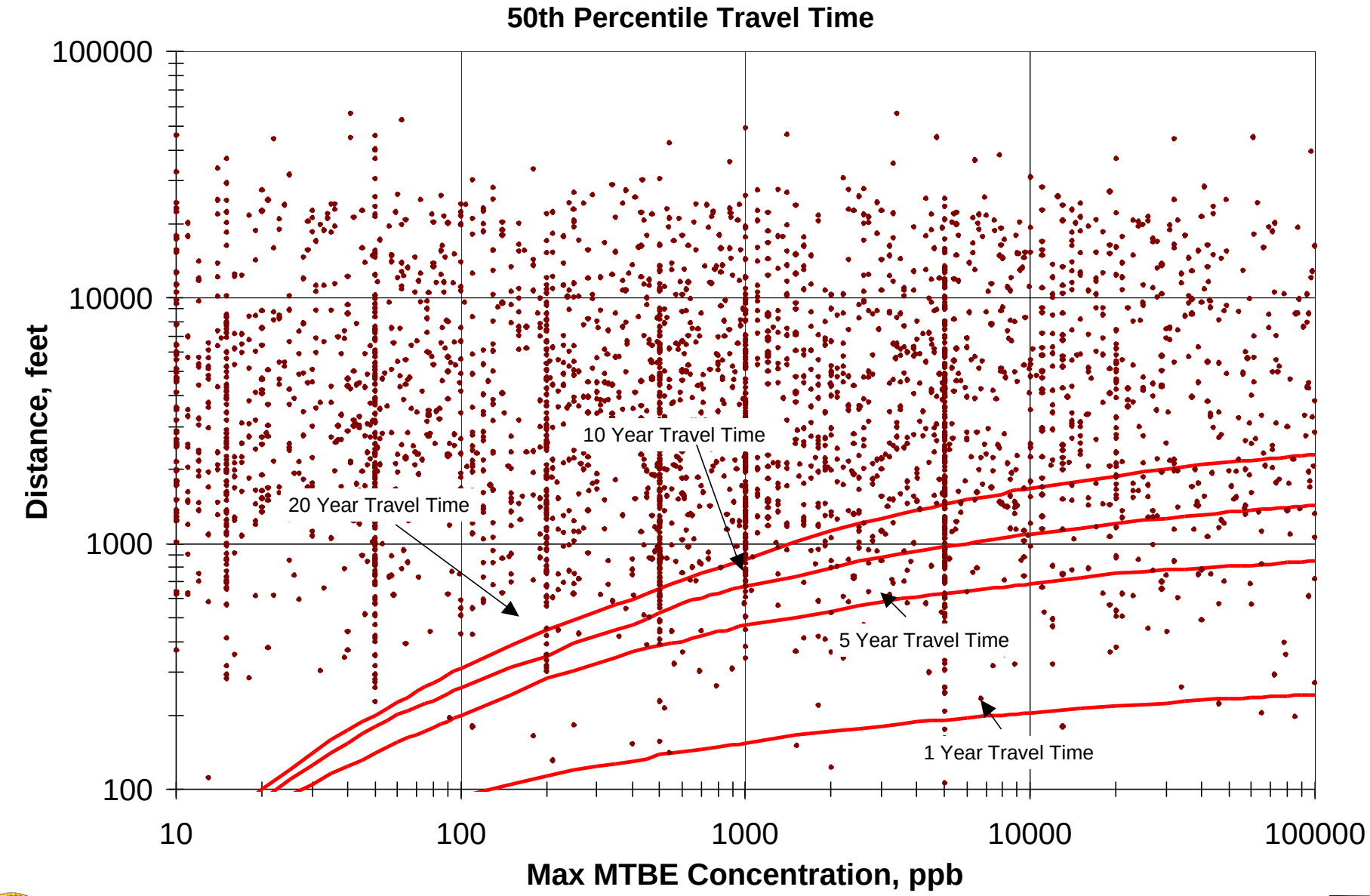


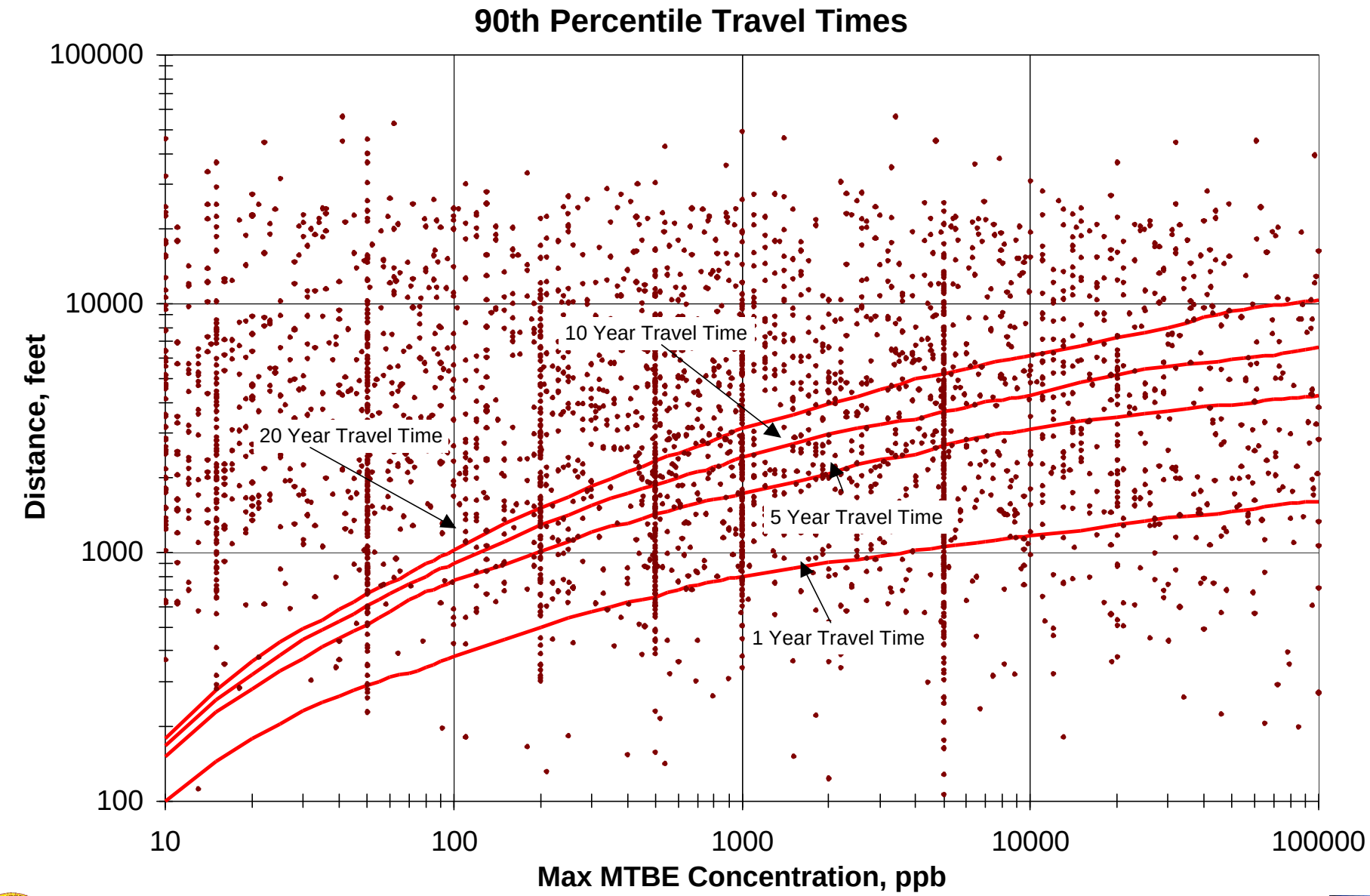
Depth to top of screen interval for different well types

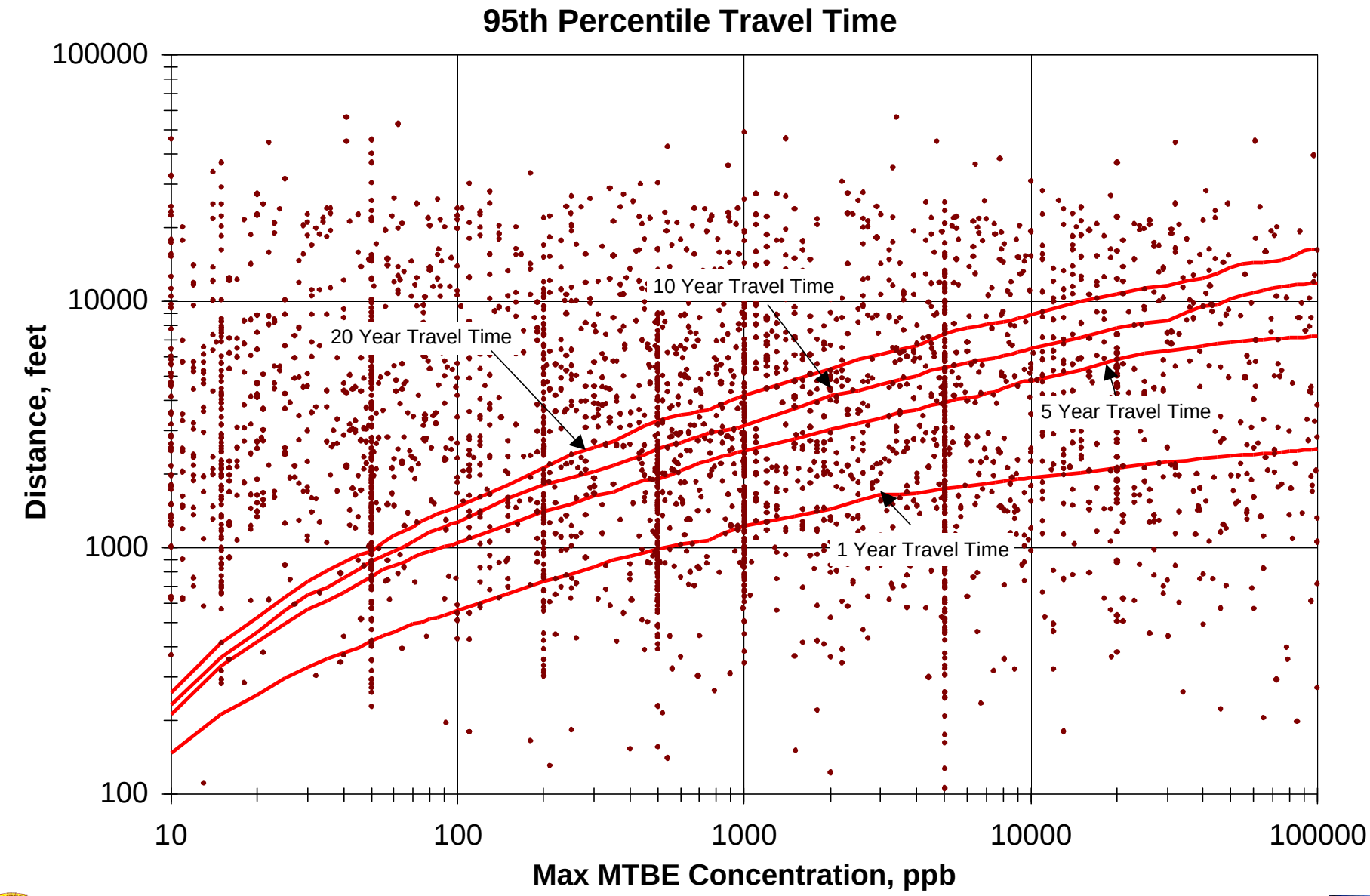



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SCVWD
Domestic
SCVWD
Municipal
0.01
0.1
1
10
100
1000
10000
Acre-feet/year


1000
100
10
1
Maximum depth to groundwater, ft
1
10
100
1000
Depth to Top of Well Screen, ft


50th Percentile Travel Time
100000
10000
1000
100
Distance, feet
10
100
1000
10000
100000
Max MTBE Concentration, ppb
20 Year Travel Time
10 Year Travel Time
5 Year Travel Time
1 Year Travel Time


90th Percentile Travel Times
100000
10000
1000
100
Distance, feet
10
100
1000
10000
100000
Max MTBE Concentration, ppb
10 Year Travel Time
20 Year Travel Time
5 Year Travel Time
1 Year Travel Time


95th Percentile Travel Time
100000
10000
1000
100
Distance, feet
10
100
1000
10000
100000
Max MTBE Concentration, ppb
20 Year Travel Time
10 Year Travel Time
5 Year Travel Time
1 Year Travel Time

Senate Bill 1189 and Assembly Bill 592 (1997)

The State Water Resources Control Board shall...

Initiate a state-wide geographical information system (GIS) to manage the threat of MTBE contamination to public groundwater supplies.

- LLNL developed the database and GIS in consultation with the Mapping and Data Management Advisory Committee.

- This system must collect, store, retrieve, analyze, and display environmental geographic data in a database that is accessible to the public.

Senate Bill 989 (1999)

The State Water Resources Control Board shall…

- Identify areas of the state most vulnerable to contamination by MTBE…
  - Criteria including but not limited to
    - Hydrogeology
    - Soil composition
    - Density of USTs in relation to drinking water wells
    - The degree of dependence on groundwater for drinking water supplies
- Identify USTs within 1,000 feet of public drinking water wells
- Allows sites under investigative orders to access DWR well logs and construction for all wells within 2 miles of the site

Assembly Bill 2886
(2000)

The State Water Resources Control Board is authorized…

- To require a person who is submitting a report relating to a program administered by the board, to the board, a regional board, or a local agency, to submit the report in electronic format, as prescribed.

Managing the Risk of MTBE Contamination on a Regional Scale

- A key to preventing MTBE contamination is early identification of vulnerable drinking water supplies and critical MTBE sources.

- A risk assessment approach prioritizes contaminant sites and groundwater supplies for monitoring and remediation.

- Currently, risk management of groundwater supplies is not possible because neither the data nor the analytical tools are readily available to environmental managers.

http://geotracker.llnl.gov/

Information Integration Initiative Goals:

Build an information network that will establish a single integrated multi-media core of environmental data and tools:

- Improve environmental decision making by integrating facility information and ambient environmental data in a geographical format.
- Reduce burden and transaction costs for access to environmental data.
- Provide more reliable and transparent access for regulated businesses.
- Provide more accurate and reliable environmental data for better public access/understanding, improved compliance, and greater accountability.

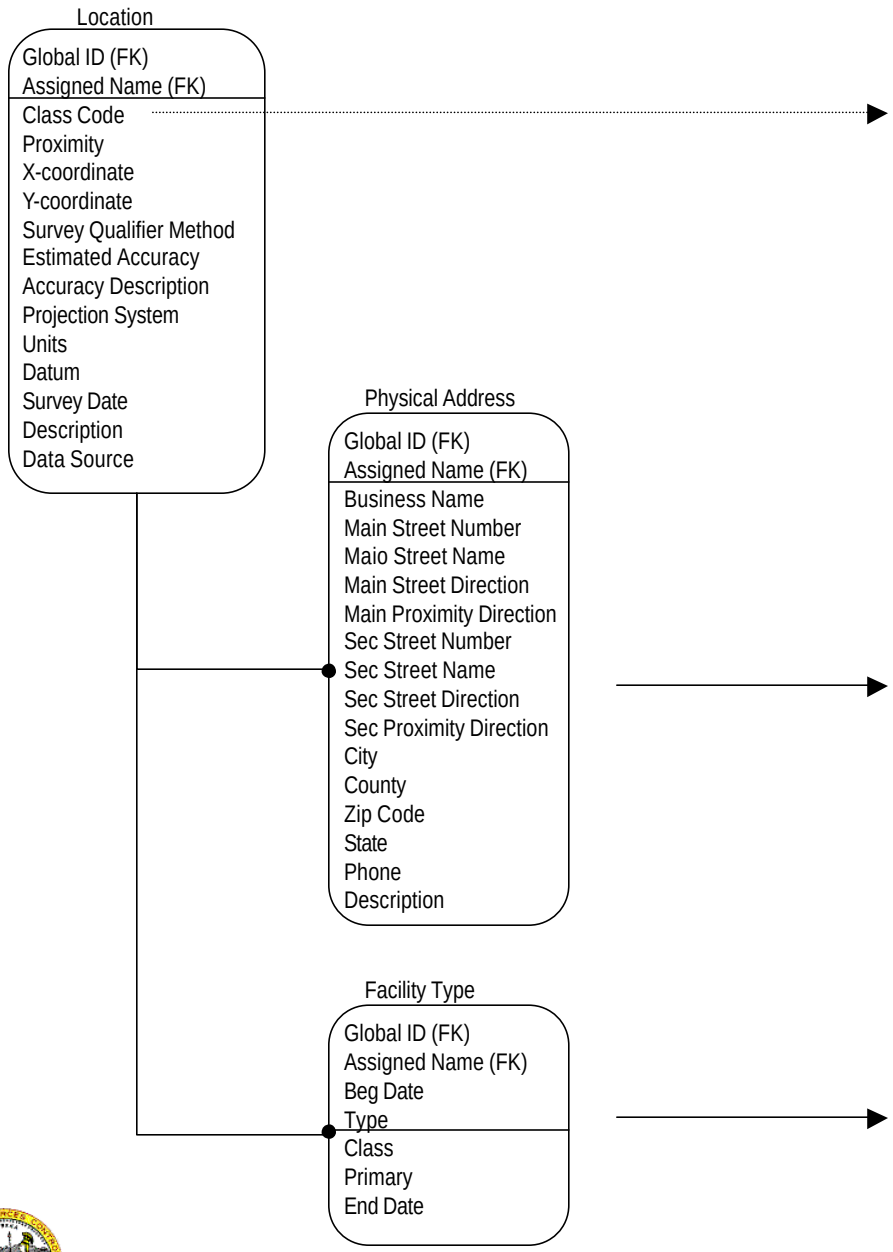
GeoTracker

- UST permit, LUFT, & drinking water program
- landfill, SLIC, NPDES, Water Rights, DOD, Beach closure, Ambient groundwater
- LTRM- Long term monitoring of residual contamination (land use planning)
- Watershed management

Soil, Water, & Vapor chemistry data from any point-source pollutant or non point-source (areal impact) and all types of groundwater resources

State-wide Base Maps….to meet case-worker daily needs for information

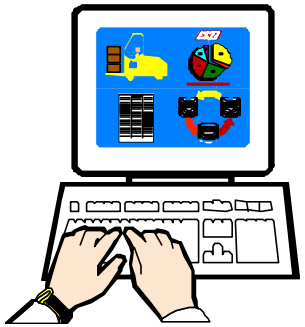
- **USGS Quads (changes projection "on-the-fly") ~40 GB**
- **ETAK street maps, ~10 GB**
- **Digital Ortho Quarter Quads, ~1 TB**
- **Groundwater Basins, 9 MB**
- **Watersheds, 5 MB**
- **DEM, slope & elevation contours**
- **Pipelines (under development, Office of the Fire Marshall)**



Drinking Well
Surface Water Intake...
UST Location
Dispenser
Borehole
Monitoring Well
Extraction Well...
Influent Monitoring Point
Effluent Monitoring Point…

Physical address

Water System
LUFT Site
Waste Water Treatment Plant
SLIC Site...
NPDS...
Standard Industrial Coding or Regulatory Descriptions



Analytical Laboratory

COELT

- Loads analytical data into EDF tables.
- Generates hard copy reports directly from electronic data.

EDF

Relational tables imported into GEIMS.

EDCC

Consistency checker for EDF format

Hard copy reports

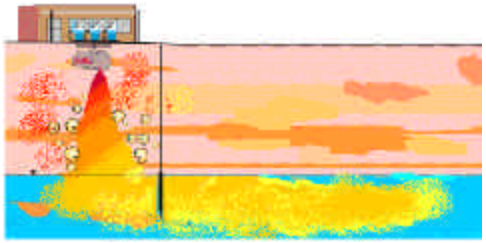
Electronic data

Environmental Contractor

Where to get public domain EDF?

http://www.arsenaultlegg.com/

Geographical-Environmental Information Management System (GEIMS) Data Transfer



FIELD SAMPLES TO LAB

LABORATORY

HARD COPY REPORT FROM EDF

EDF

RP CONSULTANT

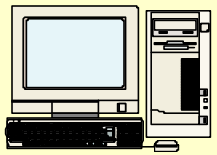
BORE LOGS LITHOLOGY DEPTH TO GROUNDWATER

SITE REGULATORY REPORT

AFTER VERIFICATION, DATA IS SUBMITTED OVER THE INTERNET TO THE STATE LUFT DATBASE (TEMPORARY FILE)

SITE DATA IS ACCESSED AND ANALYZED USING WEB TOOLS

RWQCB



LEAD AGENCY CASE WORKER

REVIEWS RP REPORT AND ELECTRONIC DATA. APPROVES RP DATA.

ENTERS/UPDATES REGULATORY FIELDS VIA INTERNET

SITE DATA IS ACCESSED AND ANALYZED BY REGULATOR USING WEB TOOLS

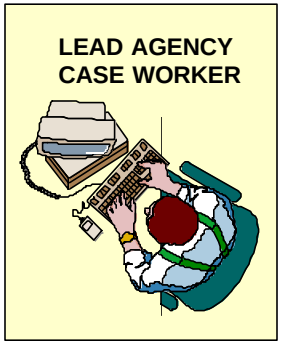
STATE SERVER ACTS AS FINAL REPOSITORY FOR CENTRALIZED DATABASE AND WEB ACCESS TOOLS

REGIONAL SERVER ACTS AS DATABASE REPOSITORY AND WEB TOOL SERVER

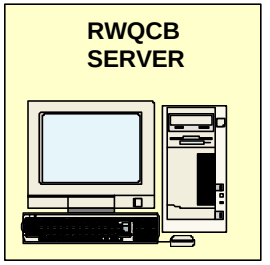
STATE UPDATES THE SWRCB SERVER

GEIMS and GeoTracker System Requirements

- COELT
- EDF
- EDCC



- Web Browser
- Datastream (optional)



- Oracle (LUFT database)
- Web server
- ESRI IMO Server
- GeoTracker

GeoTracker Benefits

- An integrated Internet site to manage data from unrelated regulatory groups
- Potential for cooperative usage among Cal-EPA agencies
  - Immediate: managing the MTBE problem
  - Long term: management of contaminant releases, water resources and environmental data
- Electronic permitting
  - Allows greater regulatory oversight
  - Reduces the paperwork burden on businesses

Introduction

We have been applying isotopes to hydrology issues in water resource management over the past 8 years. This effort began through LDRD support and has steadily grown into a program supported solely by local and state agencies. Most recently we have begun a large-scale program in conjunction with the U.S. Geologic Survey for the State of California (State Water Resources Control Board) to evaluate ambient groundwater quality throughout the entire state.

This poster covers three areas:

- Evaluation of California groundwater vulnerability
- Noble gas artificial groundwater tracers
- Tracking sources of uranium using isotope ratios

Tracer Studies in California Applied to Water Management

CAS Project

- The CAS project (California Aquifer Susceptibility) is a large-scale investigation of California groundwater resources. It represents a major paradigm shift from previous efforts. Rather than perform detailed hydrogeologic investigations, we will use simple observational data measured in water samples and use a probabilistic approach to assess contamination vulnerability.

- **GOAL:** Sample the existing 16,000 public drinking water wells in California & estimate their susceptibility to contamination.

- **SCOPE:**

  1. FY01 pilot project ($1.1M LLNL, 0.5M USGS) will investigate 500 public water supply wells.

     - Tritium & dissolved noble gases: ^{3}H-^{3}He age dating
     - Ultra low-level VOCs: e.g. MTBE, TCE, PCE
     - $^{18}O/^{16}O$ in groundwater: water origin

  2. Full scale study expected to take 5 years & about $32M

  3. Public Outreach and education are an important part of this effort. We will be working with local High School teachers & students as part of the CAS project.

     - Science on Saturday (Feb 24, 2001): Presentation about groundwater in California for children and young adults.

The Team

Brendan Dooher, Dave Rice, Walt McNab, Anne Happel, Jean Moran, Gail Eaton, Lee Davisson, Bryant Hudson

Lawrence Livermore National Laboratory

Heidi Temko, Amy Tong, Steve Mizera, Angela Schroeter, Lisa Babcock, James Giannopoulos

State Water Resources Control Board

Neil M Dubrovsky, Karen R Burow, Jennifer L Shelton, Donna Knifong

USGS

Michael Legg

Arsenault-Legg Inc.

Conclusions

- Modeling based on detailed site-specific information is needed.
- Groundwater capture zones should be included in the analysis.
- More knowledge is required concerning the subsurface environment in California.
- A drinking water well sampling frequency policy that is based on proximity to LUFT sites may be more protective of public water supplies.
- Further comparative analysis of impacted public drinking water wells to gasoline continuing ethanol or MTBE and Well Impacted LUFT sites is needed.
- A voluntary sampling program for private wells should be established by the State.

Conclusions

- With the advent of the Internet, the once difficult-to-near-impossible task of accessing data from various agencies for thousands of contaminant sites or public wells can be made simple.
- GEIMS/GeoTracker can act as an important hub for integrating information from multiple agencies about contaminant sites and water resources.
- The GIS/database approach to information management allows for an integration of data, leading to a more complete understanding of the environmental problem.

Conclusions

With the advent of the Internet, the once difficult-to-near-impossible task of accessing data from various agencies for thousands of contaminant sites or public wells can be made simple.

GEIMS/GeoTracker can act as an important hub for integrating information from multiple agencies about contaminant sites and water resources.

The GIS/database approach to information management allows for an integration of data, leading to a more complete understanding of the environmental problem.

Conclusions

Based on results from LLNL's isotope hydrology studies, Water managers are making policy decisions that affect public health in California . Given that each public water supply well costs $1-2M, these decisions have a large economic impact.

- The CAS project takes a probabilistic approach to determine the susceptibility of a public water supply well to contamination. The results from CAS project will affect decisions regarding wellhead protection, land use, and requirements for artificial recharge.
- Artificial noble gas isotope tracers give detailed hydrogeologic information on a large scale. The properties of the tracers make them ideal for defining flowpaths in groundwater intended for potable use.
- Isotopic signatures provide fingerprints for water and contaminant sources. ANCD's state-of-the-art analytical facilities for measuring isotope ratios offers a powerful suite of tools for addressing emerging water resource issues.